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THESIS

A PRELIMINARY INVESTIGATION INTO CNO AVAILABILITY SCHEDULE OVERRUNS

by

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13. ABSTRACT (maximum 200 words)

A naval vessel's "availability" is a scheduled period of time, normally conducted in a shipyard, to perform maintenance on and modernization of the vessel and its systems. The four public naval shipyards are continually challenged to complete depot-level, CNO availabilities on schedule. A naval vessel's late return to the fleet results in the decrease in operational readiness due to the reduced number of operational days available for these vessels. Subject-matter experts hypothesize that factors such as inadequate planning for resources, quantity of overtime, and quantity of work stoppages experienced contribute to availability lateness. Data collected by the shipyards are analyzed to investigate factors influencing late completion of availabilities. The analysis suggests that carrier availabilities tend to finish on schedule more often than submarine availabilities; timely availabilities tend to have a higher cost performance ratio than late availabilities; late availabilities tend to charge less for work per month in man-days than the budgeted amount of planned work; and availabilities that finish on schedule tend to have fewer work stoppages prior to start of the availability than the later completing ones.

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A PRELIMINARY INVESTIGATION INTO CNO AVAILABILITY SCHEDULE OVERRUNS

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ABSTRACT

A naval vessel’s “availability” is a scheduled period of time, normally conducted in a shipyard, to perform maintenance on and modernization of the vessel and its systems. The four public naval shipyards are continually challenged to complete depot-level, CNO availabilities on schedule. A naval vessel’s late return to the fleet results in the decrease in operational readiness due to the reduced number of operational days available for these vessels. Subject-matter experts hypothesize that factors such as inadequate planning for resources, quantity of overtime, and quantity of work stoppages experienced contribute to availability lateness. Data collected by the shipyards are analyzed to investigate factors influencing late completion of availabilities. The analysis suggests that carrier availabilities tend to finish on schedule more often than submarine availabilities; timely availabilities tend to have a higher cost performance ratio than late availabilities; late availabilities tend to charge less for work per month in man-days than the budgeted amount of planned work; and availabilities that finish on schedule tend to have fewer work stoppages prior to start of the availability than the later completing ones.

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LIST OF ACRONYMS AND ABBREVIATIONS

%OT	Percent of overtime man-days of total project man-days executed
AQWP	Actual Quantity of Work Performed
AS	Emory S. Land class Submarine Tender
AWP	Availability Work Package
BQWP	Budgeted Quantity of Work Performed
CM	Continuous Maintenance
CNO	Chief of Naval Operations
CP	Cost Performance measured as BQWP/AQWP
CVN	Nuclear Powered Aircraft Carrier
DMP	Depot Modernization Period
DPIA	Docking Planned Incremental Availability
DPL	Daily Priority List
DPMA	Docking Phased Maintenance Availability
DSRA	Docking Selected Restricted Availability
EOC	Engineered Operating Cycle
EOH	Engineered Overhaul
EPR	Execution Priorities
ERO	Engineered Refueling Overhaul
ESDRA	Extended Docking Selected Restricted Availability
IA	Inactivation Availability
IC	Interference/Coordination Work Stoppage
IMF	Intermediate Maintenance Facility
IDD	Interim Dry-Docking
JS	Job Summaries
LHD	Landing Helicopter Dock Ship
LMA	Lead Maintenance Activity
MAT	Material Work Stoppage
MMP	Major Maintenance Period
MTS	Moored Training Ship
NAVSEA	Naval Sea Systems Command

NNSY	Norfolk Naval Shipyard
NSA	Naval Supervisory Authority
OT	Overtime in man-days
PHNSY	Pearl Harbor Naval Shipyard and IMF
PIA	Planned Incremental Availability
PIRA	Pre-Inactivated Restricted Availability
PNSY	Portsmouth Naval Shipyard
PROG	Progressive Maintenance
PSNSY	Puget Sound Naval Shipyard and IMF
QAC	Quantity at Completion
RSC	Resource Work Stoppage
SAF	Safety Work Stoppage
SEA 04	Deputy Cmdr for Logistics, Maintenance and Industrial Operations
SEA 04X	Assistant Deputy Commander Industrial Operations
SEA07	Deputy Commander for Undersea Warfare
SRA	Selected Restricted Availability
SSBN	Ballistic Missile Submarine
SSGN	Guided Missile Submarine
SSN	Fast Attack Submarine
TD	Technical Direction Work Stoppage
TL	Tooling Work Stoppage
TOC	Theory of Constraints
TPAV	Availability Type
TWD	Technical Work Document
W	Workmanship/Rework
WC	Work Control

EXECUTIVE SUMMARY

This research explores various factors affecting the late completion of CNO availabilities. Availabilities are defined as the time when U.S. naval vessels are made available to maintenance activities for the accomplishment of maintenance and alterations. Timely completion of these maintenance and alteration projects is vital to maximizing fleet operational readiness and preventing cost overruns. Subject-matter experts hypothesize some factors that may contribute to availability lateness, such as:

- Inadequate planning for and availability of resources
- Underestimation of new work added to the initial work package
- Excessive quantity of over-time
- Excessive amounts of work stoppages preventing adherence to the planned schedule

Data collected by the shipyards are analyzed to identify factors contributing to late completion of availabilities.

The scope of this study covers availabilities pertaining to maintenance and alteration projects conducted on following naval vessel hulls: CVN 68, SSN 688, SSBN/SSGN 726, SSN 21, SSN 774, and LHD 1 class ships.

The lessons gained from this study offer areas for further research and investigation. The results are as follows:

- Carrier availabilities finish on schedule more often than submarine availabilities (Chapter III, Section C)
- Timely availabilities tend to have a higher cost performance ratio than late availabilities (Chapter III, Section D)
- Short submarine availabilities of fewer than 200 days are more likely to possess a greater number of days late as a percentage of planned length than longer availabilities (Chapter III, Section F)
- No clear association exists between availability lateness and the number of simultaneous availabilities underway in a shipyard (Chapter III, Section G)

- The number of days late as a percentage of planned length of an availability appears to be decreasing at most shipyards after 2006 (Chapter III, Section G)
- No clear association exists between submarine availability lateness and the number of concurrent carrier availabilities (Chapter III, Section I)
- Late availabilities tend to charge less for work per month in man-days than the budgeted amount of planned work, whereas timely availabilities tend to charge more for work per month in man-days than the budgeted amount of planned work (Chapter III, Section J)
- No clear association exists between the quantity (Chapter V, Section D) or duration (Chapter V, Section C) of work stoppages during an availability and availability lateness
- Availabilities that finish on schedule tend to have fewer work stoppages prior to availability start than late availabilities (Chapter V, Section E)

The thesis begins with a top-level data analysis to gain perspective on shipyard performance of the four Navy-owned shipyards located in Norfolk, Pearl Harbor, Portmouth, and Puget Sound. Lateness statistics of carrier and submarine availabilities are compared; the cost performance metric for late and timely availabilities are also compared. To explore possible associations with availability lateness, lateness statistics are computed for: availabilities of different scheduled lengths, availabilities conducted with differing numbers of simultaneous availabilities underway in the shipyard, availabilities completed in contiguous three year time periods during the years 2003 to 2011, and also for availabilities with various durations in inclement weather months. Additionally, the possibility of an association between submarine availability lateness and the number of simultaneous carrier availabilities underway at Puget Sound Naval Shipyard is investigated. Finally, an analysis of the historical, top-level data compares the estimate of charged time spent in completing project work (actual quantity of work performed) per month with the estimated scheduled time spent to complete project work (budgeted quantity of work performed) per month for both late and timely availabilities.

Analysis of work stoppage data investigates the effect unplanned delays, known as work stoppages, have on availability lateness. The availability's management team submits work stoppages, categorized by eight different reasons, if the planned work for a job is unable to continue. The work stoppage data are summarized in three ways in order to display commonalities and identify trends in work stoppages that are associated with availability lateness. The first two summaries organize the work stoppage data based on the mean length per work stoppage and the number of work stoppages submitted per work stoppage reason. The last summary organizes work stoppages based on the time-in-availability of work stoppage submissions.

Expansion of this research and further in-depth studies are necessary to truly understand the availability dynamic in regard to shipyard performance. This research, along with its recommendations for future and continuing studies, can assist NAVSEA and the naval shipyards leadership in understanding factors contributing to on-time and late availabilities. In addition, this research identifies factors associated with schedule lateness.

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I. INTRODUCTION

A. PURPOSE

Naval vessel maintenance and modernization is a necessary, reoccurring process to prevent decline in a vessel's operational readiness. These maintenance periods, known as "availabilities," are scheduled throughout a vessel's operational life and conducted pier side or in dry-dock. Specifically, availabilities scheduled at the highest operational level and conducted in the naval shipyards, are called Chief of Naval Operations (CNO) availabilities. Schedule management of an availability is critical in ensuring the required maintenance and modernization work is completed on time; that is, before or on the scheduled completion date, to prevent impact to fleet readiness. However, late completion of availabilities is not uncommon, and as a result Naval Sea Systems Command (NAVSEA) Deputy Commander for Undersea Warfare (SEA 07) requested a study to identify factors that can contribute to availability lateness. This thesis reports on interviews of subject-matter experts concerning factors that may influence lateness and reports the results of an analysis of availabilities' historical data across all four naval shipyards to include the following naval vessel hulls: CVN 68, SSN 68, SSBN/SSGN 726, SSN 21, SSN 774, and LHD 1 class ships.

B. PROBLEM STATEMENT

The four public naval shipyards: Puget Sound Naval Shipyard and Intermediate Maintenance Facility (PSNSY), Pearl Harbor Naval Shipyard and Intermediate Maintenance Facility (PHNSY), Norfolk Naval Shipyard (NNSY), and Portsmouth Naval Shipyard (PNSY), are continually challenged to complete submarine availabilities on schedule ("Potential Thesis Topic," NAVSEA 07, 2011). Figure 1 is a graphical representation of historical on-time availabilities from FY'05-FY'11. The historical results over the past six years show only 10%–45% of the all availabilities conducted finish on time. A slight upward trend in total on-time completion percentages is observed until most recently in FY’11, when the Naval shipyards experienced the lowest on-time completion percentage of 10%, with three of the four shipyards unable to attain any on-time completions.

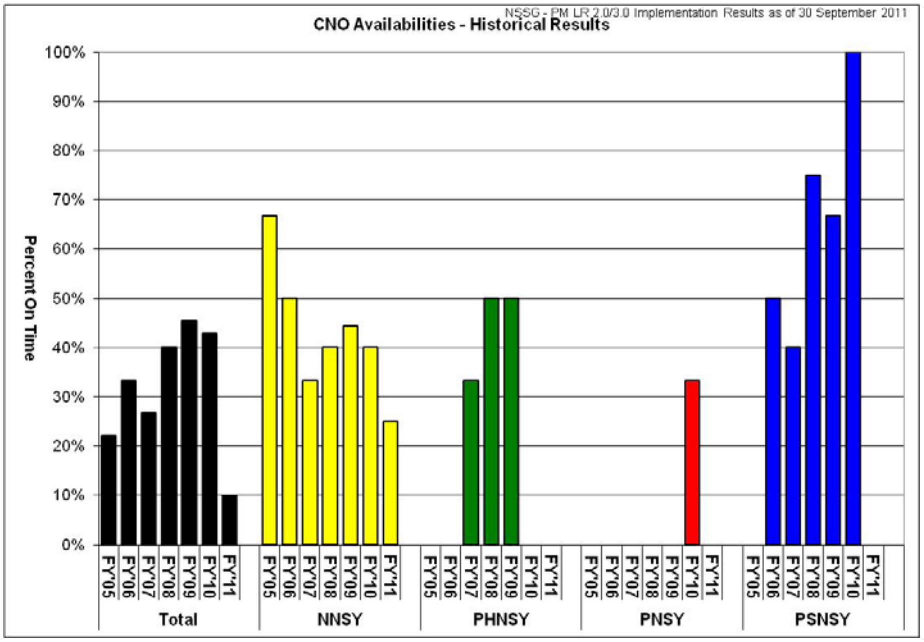

Figure 1. Historical On Time Percentages (From NAVSEA 04X 2011)

A naval vessel’s late delivery date back to operational status decreases the fleet commanders’ operational readiness due to the reduced number of operational days available for vessels held beyond the original agreed upon completion date.

C. SUBJECT-MATTER EXPERT INTERVIEWS

To identify possible causes of schedule overruns, several subject-matter experts with years of shipyard experience were consulted to identify factors they believed should influence availability lateness. Items 1–4, below, summarize the discussions. The views expressed are simply opinions from experienced and knowledgeable personnel in the field, and the intention of this thesis to further investigate the influence of these factors by analyzing historical data.

1. Inadequate Personnel Resources Result in Schedule Overruns

Multiple availabilities are simultaneously conducted in a shipyard and as a result, one availability can draw resources or personnel from other availabilities. This may happen to expedite the completion of one availability for whatever operational reason at the expense of other availabilities underway at the same time. Personnel resources can be drawn not only from other projects going on at the same shipyard, but also from projects underway at other Naval shipyards. Thus, one hypothesis is that late availabilities are the result of there not being enough experienced workers to complete the work associated with the maintenance project in a timely fashion.

2. New Work Prevents Proper Planning

Unexpected new work added to the initial work plan is underestimated, resulting in schedule overruns. Planning for an availability commences nearly two years prior to the start of the project and outlines the expected work to be done and the duration of this work is estimated. However, problems inevitably arise during the execution phase of the project and it is impossible to identify the number or scope of unexpected new work items and their impact on the initially planned schedule of work.

3. Quantity of Overtime Work is Indicative of Late Availabilities

Adherence to the day-to-day schedule of an availability prevents work delays; if work is delayed, then it must be completed in the latter months of the project. As a project runs behind schedule because of daily schedule slippages, the amount of overtime work may increase to accelerate work completion in an effort to meet schedule requirements. However, budget caps on overtime work may prevent work from being completed on time, resulting in late availabilities.

4. Work Stoppages Impact Adherence to the Planned Schedule

Work stoppages for those jobs located on or near the critical path of the project have a larger impact on schedule overruns. A critical path is defined as the longest path of consecutive activities in a project that determines the project's duration. When work is stopped, the actual durations of jobs exceed their planned durations, resulting in follow-on work to commence at a later date. More than one instance of a critical path work stoppage can result in the initially planned availability end date not being met.

D. RESEARCH QUESTIONS

The primary research questions addressed:

1. Can a statistical analysis of the planned versus actual quantity of work performed provide information on availability lateness?
2. Are there one or more public shipyards that are statistically different than the rest in terms of availability planning and execution performance?
3. Does the quantity and/or length of work stoppages affect the execution phase of an availability?
4. Can an analysis of historical work stoppage data identify possible predictors for schedule lateness?

- Does the quantity of work stoppages affect the availability’s lateness?
- Is there a common, outlying type of work stoppage present in delayed availabilities?
- Is schedule lateness associated with the timing of work stoppages over the life of the availability (i.e., early in the availability versus later in the availability)?

E. BENEFIT OF STUDY

This study presents results of analyzes of CNO availabilities historical data to identify trends, similarities, and differences between on time and late availabilities with respect to cost performance, availability length, seasonal impacts, and resource commitment in terms of manpower, work stoppages, and other factors. This study can assist the Naval Shipyard leadership in focusing on contributing factors for schedule lateness and ultimately help develop an indicator to assess an in-progress availabilities’ degree of lateness. Although there are numerous factors and variables that can lead to a schedule delay, this thesis is meant to be a foundation from which further research can be conducted to improve the planning and execution process of depot-level availabilities.

F. SCOPE OF THE THESIS

This thesis presents results of analyzes of CNO availabilities' historical data across all four public naval shipyards to include the following naval vessels hulls: CVN 68, SSN 688, SSBN/SSGN 726, SSN 21, SSN 774, and LHD 1 class ships. The chapters to follow will contain analyses pertaining to:

- Performance comparison of the four shipyards
- Lateness comparison of submarine and carrier availabilities
- Cost performances of late and timely availabilities
- Impact of availability length on lateness
- Impact of the number of simultaneous availabilities in the shipyard on lateness
- Trends of availability lateness over time
- Seasonal impacts on availability lateness
- Impacts of carrier availabilities on simultaneous submarine availabilities
- The differences in manpower resources used per month for late and timely availabilities.

Historical work stoppage data are also analyzed. The work stoppage analysis focuses on the dynamic relationship between the scheduled availability duration and the number of work stoppages. In order to understand this relationship, the work stoppage data are organized by the reasons for delay and descriptive statistics are calculated and interpreted. The work stoppage data is also summarized by the number of delays occurring per unit time during an availability. This unit of measurement results in a clearer picture on the schedule/work stoppage interaction, but also allows for the early identification of an availability schedule overrun. The ultimate goal of the work stoppage research is to present work stoppage data in a new perspective to assist and better inform SEA 07 and the naval shipyards' decision makers on the impact of work stoppages.

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II. CNO AVAILABILITY

A. INTRODUCTION

This chapter defines a CNO availability and provides notional background information on the availability planning process to include definitions specific to the Naval maintenance community.

B. CNO AVAILABILITIY DEFINED

An availability is defined as the time during which a U.S. Naval warship is made available to a maintenance activity for the accomplishment of maintenance and alterations. During an availability, the ship is rendered incapable of fully performing its assigned missions and tasks due to the nature of the repair work. The four naval shipyards analyzed in this study are considered the Naval Supervisory Authority (NSA), who is in charge of coordinating all the maintenance functions on hull, mechanical, electrical, and combat equipment and systems that are beyond the organizational capability or capacity of a ship (OPNAV N431 2010).

1. Navy Maintenance Program

The ships of the United States Navy are built with the latest technologies in the fields of structures, hydrodynamics, electrical, mechanical, and combat systems with the common goal of protecting the freedoms and executing the policies of the United States. As the responsibility to the United States Government and the people of the United States, and as described in the *Maintenance Policy for United States Navy Ships*, OPNAVINST 4700.7L, the Navy must achieve the desired operational availability levels at the lowest possible total ownership cost. The Navy's program for maintaining the readiness of its ships is separated into two distinct, yet closely related components, ship maintenance and ship modernization. The ship maintenance program is established to maintain the operational readiness of the ship and its currently installed systems; whereas the ship modernization program is established to increase ship capability and/or improve the reliability and maintainability of the existing systems.

Navy maintenance is classified into three capability levels, with each level increasing in capability required to perform the intended maintenance. The lowest maintenance level, organizational-level maintenance, consists of all maintenance actions within the capability of the ship's crew, known as ship's force. Typical organizational-level maintenance includes preventative maintenance (cleaning, lubricating, and operability testing) and corrective maintenance (component replacement and troubleshooting). This level of maintenance is promulgated by the ship specific maintenance plan. The second level, intermediate-level maintenance, is defined as the maintenance that requires skills and facilities normally beyond those of the organizational level but does not require depot-level skills. Intermediate-level maintenance is performed by fleet maintenance activities (i.e., shore-based maintenance commands, naval shipyards, and regional maintenance centers) and is promulgated by the fleet commander or authorized representative. Maintenance actions scheduled and accomplished at the intermediate-level is considered a non-CNO availability due to the nature of the repair work and ship's assigned tasking. Intermediate-level maintenance consists of but is not limited to all organizational-level maintenance, installation of alterations (modifications), provision of services (i.e., power, gas, and specific tools), and technical assistance to ship's force in diagnosing and repair.

The highest maintenance level, depot-level maintenance, consists of maintenance that requires facilities and capabilities beyond the intermediate level and is performed by the public or private shipyards. Depot-level maintenance is promulgated by the CNO, and scheduled according to the ship-class specific maintenance plan (i.e., CVN 68 class). Depot-level maintenance periods are classified as a CNO availability, which consists of but is not limited to organizational- and intermediate-level maintenance, repair and modernization of the propulsion, electric, and auxiliary plants, and structural repairs (OPNAV N431 2010).

2. CNO Availability Stakeholders

A CNO availability relies not only on one command, but rather multiple commands and supporting activities to ensure the successful planning and execution of the maintenance period. The following list lists the key stakeholders and an overview of their responsibilities:

- CNO Staff – Maintain, review, and approve maintenance program master plan for all class ships.
- Fleet and Type Commanders – Maintain the depot maintenance intervals and cycles for ships under their command, and plan for and monitor availability executions to achieve a balance of cost and schedule.
- NAVSEA – As the lead technical authority, establish performance standards for the accomplishment of all maintenance and modernizations, and to ensure the Executing Activities perform the repairs and modernization within the scope of the work authorized.
- NSA – Coordinate and integrate all maintenance actions accomplished by all Executing Activities during a CNO availability and is responsible for the on-time completion of all work.
- Lead Maintenance Activity (LMA) – Responsible for all work being accomplished, possesses the authority to organize, structure, and coordinate all execution matters.
- Executing Activities – Specific commands and private companies contracted to perform certain maintenance actions during the availability.
- Ship's Force – Maintain open communication and provide support, when needed, to NSA and the Executing Activities.

C. CNO AVAILABILITY PLANNING PROCESS

The planning phase for a CNO availability starts as far out as two years prior to the availability start date, with the initial issue of the Availability Work Package (AWP). The AWP consists of maintenance actions, known interchangeably as work items or jobs, and ship alterations identified by ship's force, NAVSEA, and other supporting engineering commands, known as codes. The initial AWP identifies the known work and class alterations that must be completed during the availability. Additional work items are identified and added to the AWP during work discovery periods scheduled during the planning phase. The discovery periods are conducted by ship's force with oversight and assists from the fleet support activities that specialize in pre-availability testing and ship deficiency identification.

Job summaries (JSs) are created for all work items in the AWP and are the fundamental planning elements that allow an availability's project schedule to be determined. A JS identifies the instructions relevant to the job; breaks down the required work necessary for job completion; and allows for the planning of resources and control of work during the execution phase. JSs are created by the engineering and planning codes and are then issued to the availability's management team for review. The review accounts for accuracies in skill designations, and sufficiency in durations and management ability. The JS review is an iterative process and continues until all required work and resources are approved and are written into Technical Work Documents (TWDs). Upon start of the availability and the execution phase, TWDs are issued to the Executing Activities, providing specific instructions on the work needing completion ("Baseline Project Management Plan," NAVSEA 07, 2009).

D. AVAILABILITY TYPES AND MAINTENANCE PHILOSOPHIES

The following section contains a list describing the different types of availabilities that are performed at the four naval shipyards as defined by *Representative Intervals, Duration, and Repair Mandays for Depot Level Maintenance Availabilities of U.S. Navy Ships*, OPNAVNOTE 4700.

1. Progressive Maintenance (PROG)

A maintenance philosophy designed to support ships with reduced manning, limited organizational level maintenance, and operational tempos that limit availability periods. It is also designed to sustain a high level of readiness and increase the ship's availability for required operations.

2. Engineered Operating Cycle (EOC)

A maintenance philosophy to keep ships in an acceptable material condition while sustaining or increasing the operational availability of the ship; it is earmarked by a structured engineered approach for ship maintenance while minimizing time spent in depot-level availabilities.

3. Selected Restricted Availability (SRA)

A short intensive industrial period assigned to ships in PROG or EOC maintenance programs for the accomplishment of maintenance and selected modernization, where ships assigned to PROG are maintained through SRAs in lieu of overhauls.

4. Engineered Refueling Overhaul (ERO)

A major availability comprised of maintenance and modernization work items; normally exceeding six months in duration.

5. Inactivation Availability (IA)

"An availability assigned to prepare a ship for inactivation or disposal."

6. Docking Selected Restricted Availability (DSRA)

"An SRA expanded to include maintenance and modernization that require dry-docking."

7. Phased Maintenance (PM) and Phased Maintenance Availability (PMA)

A maintenance philosophy that uses depot level maintenance through a series of short, frequent labor-intensive PMA in lieu of regular overhauls. The goals of PM are to maximize ship availability, improve operational readiness, and upgrade material condition.

8. Docking Phased Maintenance Availability (DPMA)

A PMA in which the AWP requires dry-docking.

9. Depot Modernization Period (DMP)

An availability scheduled primarily for the installation of major alterations.

10. Extended Docking Selected Restricted Availability (EDSRA)

An extended DSRA allowing for a larger AWP.

11. Interim Dry-Docking (IDD)

"A hull specific availability used to extend the operating cycle prior to the next major maintenance availability."

12. Major Maintenance Period (MMP)

"An on-site non-CNO availability for SSGNs for the accomplishment of maintenance and modernization."

13. Continuous Maintenance (CM)

"Scheduled depot level maintenance conducted outside of CNO availabilities."

14. Incremental Maintenance Plan (IMP)

"A maintenance philosophy which ensures aircraft carriers are kept in an acceptable material condition through a series of incremental depot maintenance actions. Aircraft carriers assigned to IMPs are maintained through PIAs and DPIAs, defined next, in lieu of overhauls."

15. Planned Incremental Availabilities (PIA)

Maintenance and modernization work items are accomplished in this labor-intensive availability of less than six months in duration for aircraft carriers in an IMP.

16. Docking Planned Incremental Availabilities (DPIA)

In this labor-intensive availability of less than one year in duration for aircraft carriers in an IMP, maintenance and modernization are accomplished in dry-dock.

E. SUMMARY

This chapter gave information pertaining to shipyard availabilities and provided information concerning of the differences in the types of availabilities conducted at the four shipyards.

III. TOP-LEVEL SHIPYARD PERFORMANCE DATA ANALYSIS

A. INTRODUCTION

The top-level shipyard performance data are obtained from the Assistant Deputy Commander Industrial Operations (SEA 04X). SEA 04X is a supporting department under the Deputy Commander for Logistics, Maintenance and Industrial Operations (SEA 04). SEA 04X is the reporting command for all four public shipyards in regard to business and technical matters and is responsible for providing methodological oversight and for maintaining standardized practices and engineering methods across the public shipyards (NAVSEA 04Z 2011). In addition, SEA 04X collects and analyzes shipyard data and metrics in order to provide accurate performance measurements. These performance measurements allow SEA 04 to formulate and implement performance improvement techniques.

The data are in the form of an Excel spreadsheet. The data consists of several different performance metrics for availabilities that occurred in the four Navy-owned shipyards dating as far back as 2001. Data are available for a total of 108 historical availabilities, 23 of which were conducted at Pearl Harbor Naval Shipyard, 34 conducted in Norfolk Naval Shipyard, 21 in Portsmouth Naval Shipyard, and 30 in Puget Sound Naval Shipyard. The data also include 18 availabilities that are still underway at the time of this analysis, with three in Norfolk, four in Pearl Harbor, five in Portsmouth, and six in Puget Sound. Data for completed availabilities and data for on-going availabilities were initially separated so that a study could be made for completed availabilities. In the remainder of this chapter only data from completed availabilities are considered.

B. DATA SET DESCRIPTION

The data set displays the project name, along with hull type, hull number, and shipyard in which the availability took place. For each project there are data for budgeted and actual quantity of work performed (BQWP and AQWP respectively); cost performance (CP = BQWP/AQWP); quantity of overtime work in man-days; the percentage the overtime work is of all actual work performed (OT and %OT); and the number of days the complete project is late (negative days are associated with projects finishing early). The budgeted quantity of work performed describes, in man-days, the earned value of work completed whereas the actual quantity of work performed describes the charged value of work performed in completing the availability ("Baseline Project Management Plan," NAVSEA 07, 2009). Figure 2 displays an example of one of the data sets: the USS JEFFERSON CITY, a Depot Modernization Project occurring in Puget Sound Naval Shipyard during the period 2003 to 2004.

Project ID	Project Title	Type	Hull	Avail Type	SY	BQWP	AQWP
S59	JEFFERSON CITY	SSN	759	DMP	PSNSY	190,604	239,824

Start	Actual End	CP	OT	%OT	Orig CA00	On Time? 1=Yes; 0=No	Days Late	End FY
2/15/03	8/1/04	0.79	46,912	19.60%	3/15/04	0	139	FY'04

Figure 2. Sample SEA 04X Historical Availability Data

As can be seen, the project identification number is given (S59) as well as the project title, hull type (SSN), hull number (759), availability type (DMP), and the associated shipyard where the availability took place is also given (PSNSY). Days late can be either a positive or negative number, with a positive number meaning the project went beyond the planned end date and a negative number meaning the project was complete a certain number of days prior to the planned end.

C. COMPARING THE SHIPYARDS

The number of days late for completed availabilities in each shipyard is first investigated. Tables 1 through 4 display the number of availabilities completed on-time or late between 1 and 30 days, 31 to 60 days, 61 to 90 days, and availabilities late by 91 days or more. Figures 3 through 6 display the summaries graphically. The histogram data is displayed in Appendix A.

	% Frequency
Ahead of schedule	15 of 34 = 44.10%
Finish btw 1-30 days late	5 of 34 = 14.70%
Finish btw 31-60 days late	9 of 34 = 26.50%
Finish btw 61-90 days late	2 of 34 = 5.90%
Finish more than 90 days late	3 of 34 = 8.80%

Table 1. Availability Completions For Norfolk Naval Shipyard

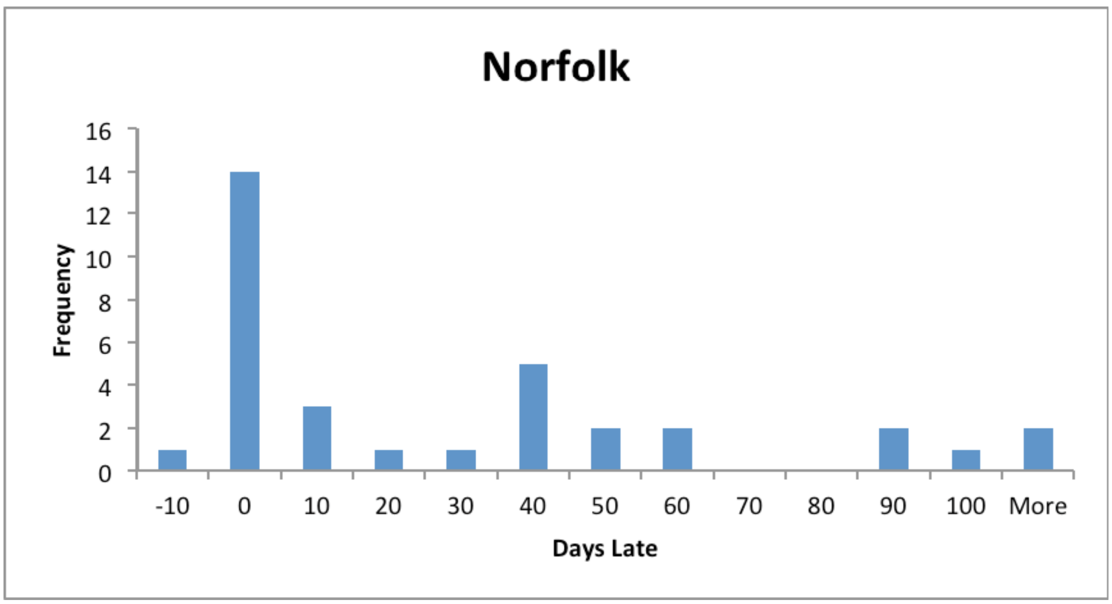

Figure 3. Number of Completed Availabilities at Norfolk Naval Shipyard

	% Frequency
Ahead of schedule	4 of 23 = 17.40%
Finish btw 1-30 days late	7 of 23 = 30.40%
Finish btw 31-60 days late	3 of 23 = 13.00%
Finish btw 61-90 days late	4 of 23 = 17.40%
Finish more than 90 days late	5 of 23 = 21.70%

Table 2. Availability Completions For Pearl Harbor Naval Shipyard

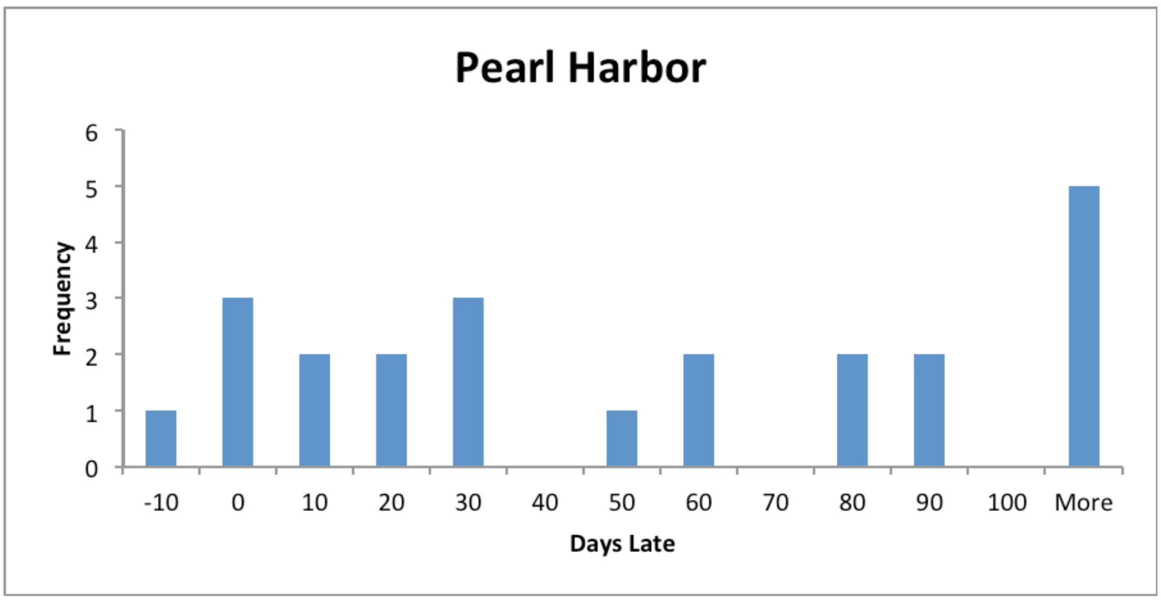

Figure 4. Number of Completed Availabilities at Pearl Harbor Naval Shipyard

	% Frequency
Ahead of schedule	3 of 21 = 14.30%
Finish btw 1-30 days late	6 of 21 = 28.60%
Finish btw 31-60 days late	3 of 21 = 14.30%
Finish btw 61-90 days late	3 of 21 = 14.30%
Finish more than 90 days late	6 of 21 = 28.60%

Table 3. Availability Completions For Portsmouth Naval Shipyard

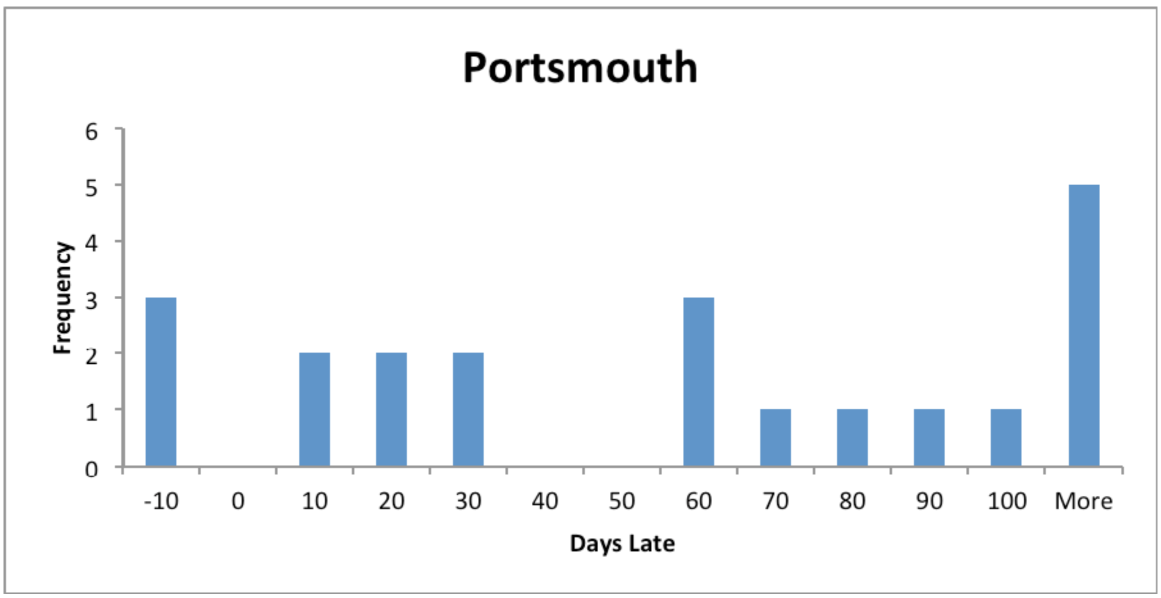

Figure 5. Number of Completed Availabilities at Portsmouth Naval Shipyard

	% Frequency
Ahead of schedule	15 of 30 = 50.00%
Finish btw 1-30 days late	8 of 30 = 26.70%
Finish btw 31-60 days late	2 of 30 = 6.70%
Finish btw 61-90 days late	1 of 30 = 3.30%
Finish more than 90 days late	4 of 30 = 13.30%

Table 4. Availability Completions For Puget Sound Naval Shipyard

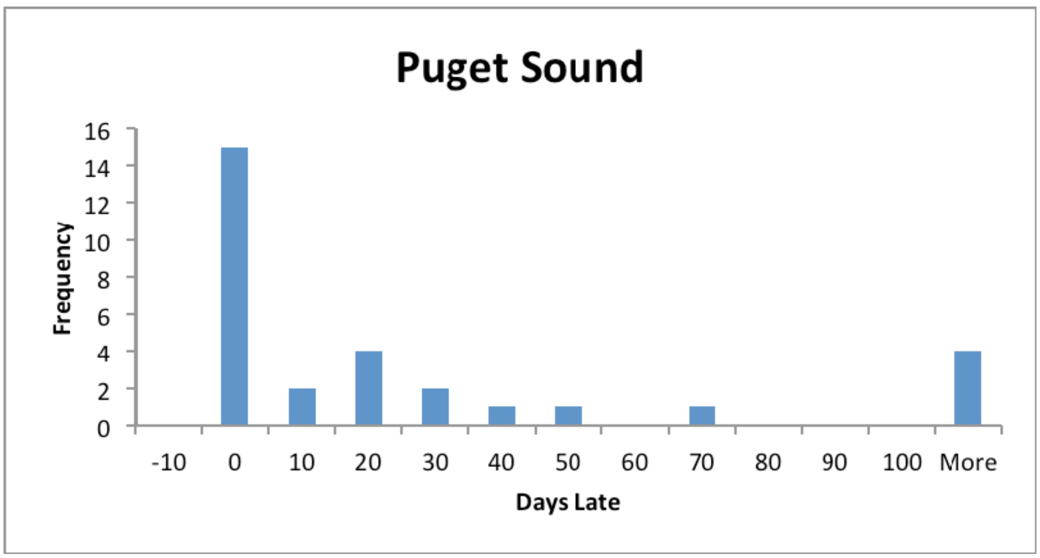

Figure 6. Number of Completed Availabilities at Puget Sound Naval Shipyard

It is apparent that a majority of availabilities at three of the four shipyards end after the planned completion date. Only Puget Sound Naval Shipyard has 50 percent of availabilities completed on-time or ahead of schedule. Table 5 displays the actual percentage of availabilities that ended late at each of the four shipyards dating as far back as 2001:

Shipyard	Percentage of Availabilities that are Late	Number of Availabilities	Standard Error
Norfolk	55.90%	34	8.50%
Pearl Harbor	82.60%	23	7.90%
Portsmouth	85.70%	21	7.60%
Puget Sound	50.00%	20	11.20%

Table 5. Percentage of Completed Availabilities Ended Late from 2001 to 2011

The percentages in Table 5 are associated with the corresponding number of availabilities shown. Since the percentages are based on a small number of data (only 20 through 34), the standard error of the percentage of availabilities late is shown to provide an estimate of the possible range of percentages. For example, one could estimate that the true mean percentage of availabilities that are late at Norfolk Naval Shipyard as between 47.4% and 64.4% (55.9% ± 8.5).

Table 6 (respectively, Table 7) displays the percentage of completed availabilities that are late for both submarines and carriers. The results suggest that carrier availabilities typically finish in a more timely manner than submarine availabilities.

Shipyard	Late Submarine Availability Percentage	Number of Availabilities	Standard Error
Norfolk	62.50%	13	13.40%
Pearl Harbor	82.60%	23	7.90%
Portsmouth	85.00%	20	8.00%
Puget Sound	62.50%	16	12.10%

Table 6. Percentage of Submarine Availabilities Ended Late per Shipyard

Shipyard	Late Carrier Availability Percentage	Number of Availabilities	Standard Error
Norfolk	36.40%	11	14.50%
Pearl Harbor	N/A	0	N/A
Portsmouth	N/A	0	N/A
Puget Sound	30.80%	13	12.80%

Table 7. Percentage of Carrier Availabilities Ended Late per Shipyard

These tables raise several questions: "Why are carrier availabilities outperforming submarine availabilities?" and "Could there be a statistically significant difference between the performance of Norfolk and Puget Sound and the performance of Portsmouth and Pearl Harbor in completing submarine availabilities in a timely fashion?" The percentages and associated standard errors so far do not indicate a statistically significant difference between the results at the different shipyards. However, there is a statistically significant difference between the mean late percentages of carrier availabilities and submarine availabilities. In this context, claiming that the means of two sets of data are statistically significantly different implies that the two means cannot be accepted as equal or similar, based on the differences of the means as well as the spread of the plausible mean values for each data set as illustrated by the standard error. Two sample t-tests, with the assumption that the means of the two sets of data have unequal variances, are conducted via computer software such as Microsoft Excel to determine if the means of two sets of data are statistically significantly different. Additional information on this approach appears in Section D.

D. COMPARING THE COST PERFORMANCE MEANS

In this section, associations between cost performance, overtime percentage, and the lateness of the availability are studied. In particular, the possible association between cost performance (CP = BQWP/AQWP) and overtime percentage (OT%) between projects ending late and projects ending on-time or ahead of schedule is investigated. Table 8 displays the descriptive statistics for the four shipyards:

		CP				OT%	
		Late	Not Late			Late	Not Late
Norfolk	**Mean:**	0.87	0.93	Norfolk	**Mean:**	20.5	20.2
	StDev:	0.09	0.07		**StDev:**	6.8	4.8
	StError:	0.02	0.02		**StError:**	0.02	0.01
	Sample Size:	19	15		**Sample Size:**	19	15
Pearl Harbor	**Mean:**	0.83	0.92	Pearl Harbor	**Mean:**	20	17.7
	StDev:	0.08	0.08		**StDev:**	4.1	4.22
	StError:	0.02	0.04		**StError:**	0.01	0.02
	Sample Size:	19	4		**Sample Size:**	19	4
Portsmouth	**Mean:**	0.9	1.03	Portsmouth	**Mean:**	20.6	20.3
	StDev:	0.08	0.14		**StDev:**	7.4	8.05
	StError:	0.02	0.08		**StError:**	0.02	0.05
	Sample Size:	18	3		**Sample Size:**	18	3
Puget Sound	**Mean:**	0.87	0.97	Puget Sound	**Mean:**	19.1	16.1
	StDev:	0.1	0.06		**StDev:**	5.4	3.05
	StError:	0.03	0.02		**StError:**	0.01	0.01
	Sample Size:	15	15		**Sample Size:**	15	15

Table 8. Mean Cost Performances and Overtime Percentages for the Four Shipyards

With this information, a comparison is made between the population means of CP and OT% for late and timely availabilities across all shipyards with the assumption that the samples are independent and have unequal variances. The null hypothesis in this analysis is that the mean CP for late projects equals the mean CP of on-time projects. If the null hypothesis is rejected, then the alternative hypothesis that there is a statistically significant difference between the two means is accepted. The t-statistic for the null hypothesis is computed using equation 1:

$$t = \frac{meanCPlate - meanCPnotlate}{\sqrt{\frac{(StDevLate)^2}{SampleSize} + \frac{(StDevNotLate)^2}{SampleSize}}}$$

Equation 1. T-statistic to Test Significant Differences between CP Population Means

The t-statistic for the null hypothesis may either fall in the acceptance or rejection region as determined by the critical t-value $t_{\alpha/2,n-1}$, where n stands for smaller sample size of the two populations being compared. The null hypothesis is rejected if $|t| > t_{\alpha/2,n-1}$ (Hayter 2007). Results are displayed in Table 9 comparing CP and overtime percentages for all availabilities across all shipyards.

	CP	OT%
Mean Late	0.87	0.2
Variance Late	0.008	0.004
Mean On-Time	0.95	0.18
Variance On-Time	0.006	0.002
Confidence Level	95%	95%
t-statistic	5.28	1.76
critical t-value	1.99	1.99
P-value	9.70E-07	0.081
Reject null?	Yes	No

Table 9. Results in Testing for Significant Difference of the Means for Cost Performance and Overtime Percentage

Table 9 displays the mean CP and overtime percentage for late and timely availabilities across the four shipyards. The variance for each value gives an indication of the spread of the values for each data set. The results suggest that there is a significant difference between the CP for projects that finish on-time and those that end late. The results for OT% do not necessarily show conclusive evidence that the means are significantly different. From this, it is concluded that the overtime percentages for late and timely availabilities are statistically similar.

E. COST PERFORMANCE GOAL

Availabilities that finish late tend to possess a CP which is less than the CP of on-schedule availabilities that finish early or on time. The possibility of specifying a CP to strive for in order to ensure a timely availability is investigated. One-sided t-confidence intervals are constructed based on the given data sets to determine a lower 99% confidence bound for the average CP for those availabilities that finished on time or ahead of schedule and an upper 99% confidence bound for those availabilities that finished late. The one-sided confidence interval formula appear in equations 2 and 3; μ is the sample mean and s is the sample standard deviation:

$$Upper\_confidence\_bound = (-\infty, \mu + \frac{(t_{\alpha,n-1})s}{\sqrt{n}})$$

Equation 2. Upper Confidence Bound for CP of Late Availabilities

$$Lower\_confidence\_bound = (\mu - \frac{(t_{\alpha,n-1})s}{\sqrt{n}}, \infty)$$

Equation 3. Lower Confidence Bound for CP of Timely Availabilities

The sample means, standard deviations, and sample sizes are computed from the data sets reflecting all the completed availabilities across the four shipyards and all hull types. Table 10 displays the descriptive statistics of the data as well as the upper-bound of the confidence interval for the late availabilities and the lower-bound of the confidence interval for the on-time availabilities. A confidence level of 99%was used for the confidence intervals. In addition, the quantiles of the data are displayed to illustrate the percentage of availabilities with certain CPs.

Cost Performance for Late Availabilities				
Descriptive Statistics		**Quantiles**		
Mean	0.87	100.00%	maximum	1.06
Std Dev	0.09	90.00%		1
Std Err Mean	0.01	75.00%	quartile	0.93
Upper 99% Confidence Bound	0.89	50.00%	median	0.87
Num Avails	71	25.00%	quartile	0.81
		10.00%		0.75
		0.00%	minimum	0.62

Cost Performance for On-Time Availabilities				
Descriptive Statistics		**Quantiles**		
Mean	0.95	100.00%	maximum	1.19
Std Dev	0.08	90.00%		1.04
Std Err Mean	0.01	75.00%	quartile	1.01
Lower 99% Confidence Bound	0.92	50.00%	median	0.95
Num Avails	37	25.00%	quartile	0.89
		10.00%		0.86
		0.00%	minimum	0.83

Table 10. Cost Performance Data Comparison for Late and Timely Availabilities

Figure 7 displays a histogram of the CP ratio for availabilities that finish late and availabilities that finish early or on time. The results of Table 10 suggest that one could say with 99% confidence that late availabilities will have a mean CP ratio of 0.89 or less and that on-time availabilities will have a mean CP of 0.92 or higher. However, it appears that there is a large overlap of CP values among late availabilities and on-time/early availabilities. Twenty-five percent of late availabilities have a CP ratio of 0.93 or higher, whereas twenty-five percent of on-time availabilities have a CP ratio of 0.89 or lower. Although management can strive to ensure a CP ratio of 0.92 or higher, it does not necessarily guarantee a timely availability.

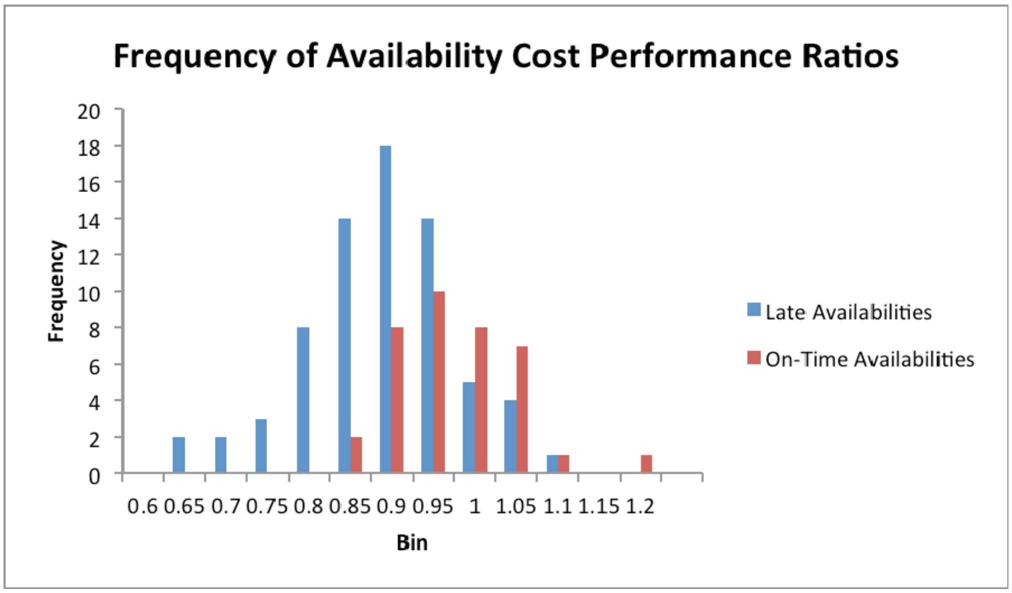

Figure 7. Frequency of Cost Performance Ratios for Late and Timely Availabilities

E. DAYS LATE VERSUS AVAILABILITY LENGTH

In this section, associations between availability length and the lateness of the availability are studied. In this case, longer availabilities are availabilities with longer planned lengths due to the quantity of jobs in the work package and their associated expected times to completion. The availabilities are arbitrarily partitioned into 3 categories: short with scheduled length less than or equal to 200 days; medium with a scheduled length between 200 and 400 days; and long with a scheduled length of 400 days or greater. Of the 108 completed availabilities considered, 52 had lengths of 200 days or fewer, 27 had lengths between 200 and 400 days, and 29 had lengths of 400 days or greater. The availabilities consist of various hulls, including carriers, submarines (SSN, SSBN, and SSGN), as well as Landing Helicopter Dock (LHD) amphibious assault ships across all four the shipyards. Roughly 70% of the data are from submarine availabilities and 22% are from carrier availabilities. Table 11 displays the percentage of availabilities ending on time for each of the three availability length ranges.

	Availability Length		
	0-200 Days	200-400 Days	400+ Days
# Availabilities	52	27	29
% Late	59.60%	66.70%	75.90%
% Late Std Error	6.80%	9.10%	7.90%
Mean Length	131	332	694
Mean Days Late	44.5	50.2	106
Mean Days Late %	42.40%	14.30%	16.70%
Mean Days Late % Standard Error	6.90%	6.70%	6.90%

Table 11. Lateness Statistics of Availabilities of Various Lengths

Table 11 suggests that the longer availabilities are late a greater percentage of the time than the shorter availabilities, perhaps indicating that larger availabilities have a greater probability of ending late than shorter ones. However, the standard errors are large enough to indicate that there is no statistically significant difference between the percentage of availabilities that are late for each category of availabilities. The row labeled "mean late %" represents the number of days late as a percentage of the initial planned length of the availability (for the late availabilities), and it is seen from the table that, on a percentage basis, shorter availabilities that are late typically have a percentage of late days far greater than the longer availabilities that are late (42% versus 14% to 16%). A two sample t-test has shown that there is a statistically significant difference in the 'mean late %' for the short availabilities (0–200 days length) and the longer availabilities. This can be an indication of inaccurate planning for the shorter availabilities or an inadequate amount of buffer space allowed in the schedule for unexpected issues, work stoppages, or new work. There is no statistically significant difference in the ‘mean late days %’ for the medium (200–400 day length) and long (400 days or more) availabilities. Table 12 displays summary statistics to consider submarine availabilities and carrier availabilities separately and the various results based on availability length.

	Submarine-only Availability Length		
	0-200 Days	200-400 Days	400+ Days
# Availabilities	31	15	29
% Late	71.00%	80.00%	75.90%
% Late Std Error	8.2	10.3	7.9
Mean Length	113	356	694
StDev Length	33	40	193
Mean Days Late	48	62	106
Mean DaysLate %	50.70%	17.00%	16.70%
Mean Days Late % Std Error	9	9.7	6.9

	Carrier-only Availability Length		
	0-200 Days	200-400 Days	400+ Days
# Availabilities	16	8	0
% Late	31.25%	37.50%	N/A
% Late Std Error	11.6	17.1	N/A
Mean Length	160	295	N/A
StDev Length	38	54	N/A
Mean Days Late	17	49	N/A
Mean Days Late %	11.07%	22.80%	N/A
Mean Days Late % Std Error	7.8	14.8	N/A

Table 12. Lateness Statistics of Submarine and Carrier Availabilities of Various Lengths

When the data are summarized by the number of days late as a percentage of availability planned length, submarine projects between 0 and 200 days have a mean percentage that is substantially higher than the mean percentage of days late for longer submarine projects. The following plot may offer a better illustration of availability length on days late as a percentage of planned length.

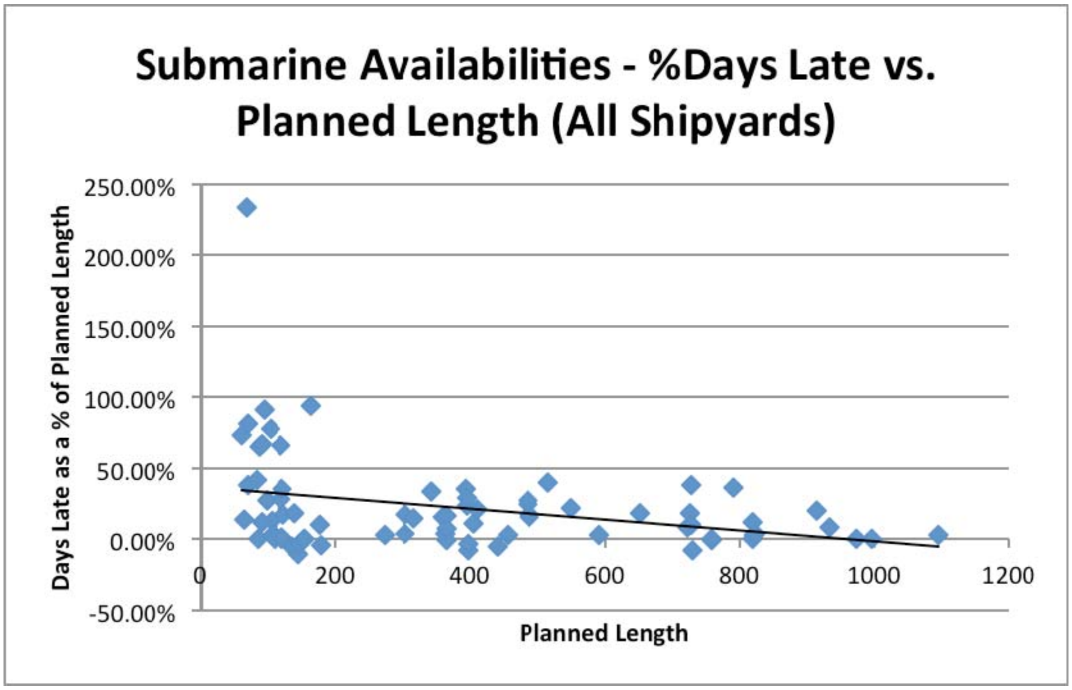

Figure 8. Days Late Percentage as a Function of Planned Availability Length

In Figure 8, the variability of the percentages of availability lateness is roughly the same for availabilities between 200 days to 800 days. Of the 31 availabilities with scheduled length less than or equal to 200 days, 9 are late by more than 50% of their scheduled availability length. Of these 9 availabilities, 7 of them completed in 2006 or earlier, two completed in 2008, and 0 had a days late percentage of 50% or higher after 2008. This possibly indicates an improvement in submarine availability days late percentages over time.

Figure 9 displays the number of days late versus availability length; the plot includes all availability types and all hulls. It can be seen that many short availabilities are late by as many days as availabilities 400, 600, or 1000 days in length. Table 13 displays the percentage of short, medium, and long availabilities that are either on time, late up to 30 days, late between 31 and 60 days, or late more than 60 days. A t-test comparing the mean days late for short and medium availabilities reveals no statistically significant difference, despite the 200 day difference in average availability length.

Short Availabilities (0 to 200 days in length)			
Days Late	Number of Availabilities	Percentage of Total	Standard Error of Percentage
<= 0	21	40.40%	6.80%
1 to 30	15	28.80%	6.30%
31 to 60	9	17.30%	5.20%
60+	7	13.50%	4.70%

Medium Availabilities (200 to 400 days in length)			
Days Late	Number of Availabilities	Percentage of Total	Standard Error of Percentage
<= 0	9	33.30%	9.10%
1 to 30	8	29.60%	8.80%
31 to 60	5	18.50%	7.50%
60+	5	18.50%	7.50%

Long Availabilities (400+ days in length)			
Days Late	Number of Availabilities	Percentage of Total	Standard Error of Percentage
<= 0	7	24.10%	7.90%
1 to 30	3	10.30%	5.70%
31 to 60	3	10.30%	5.70%
60+	16	55.20%	9.20%

Table 13. Lateness Frequencies of Availabilities of Various Lengths

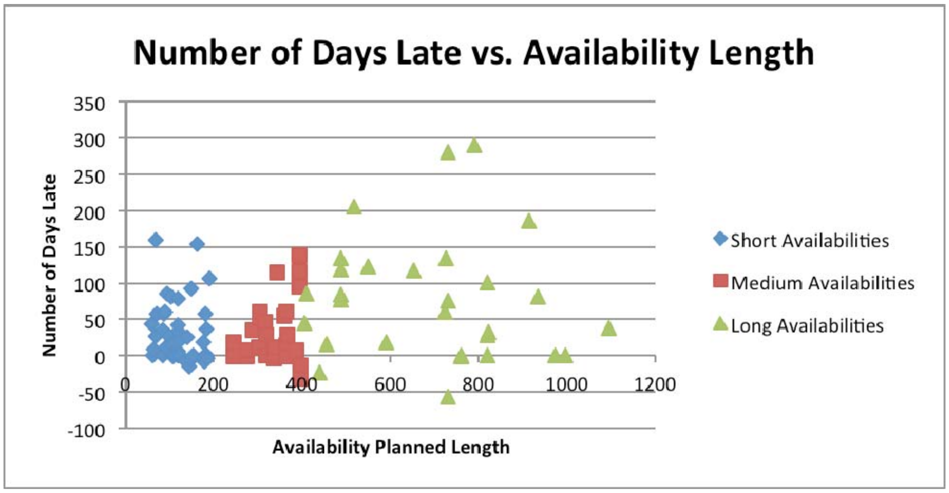

Figure 9. Number of Days Late as a Function of Planned Availability Length

F. NUMBER OF AVAILABILITIES IN THE SHIPYARD VERSUS THE NUMBER OF DAYS LATE AS A PERCENTAGE OF PLANNED AVAILABILITY LENGTH

In this subsection, associations between number of availabilities being conducted in a yard and availability lateness is studied. For instance, availabilities may be more likely to be late and have a greater number of days late as a percentage of planned length if there are a total of 8 availabilities going on at the shipyard, causing the shipyard to use more of its resources and to operate at close to maximum capacity as opposed to operating at 50% capacity with only 4 availabilities underway. Gantt charts are constructed for each of the four shipyards illustrating the historical schedule of all the availabilities that took place in each shipyard dating as far back as 2001 and extending all the way to as recent as 2011. The Gantt charts are effective in showing the number of total availabilities as well as the different kinds of vessels being worked on across certain time periods. Figure 10 displays the Gantt chart for data from Norfolk Naval Shipyard between 2005 and 2009.

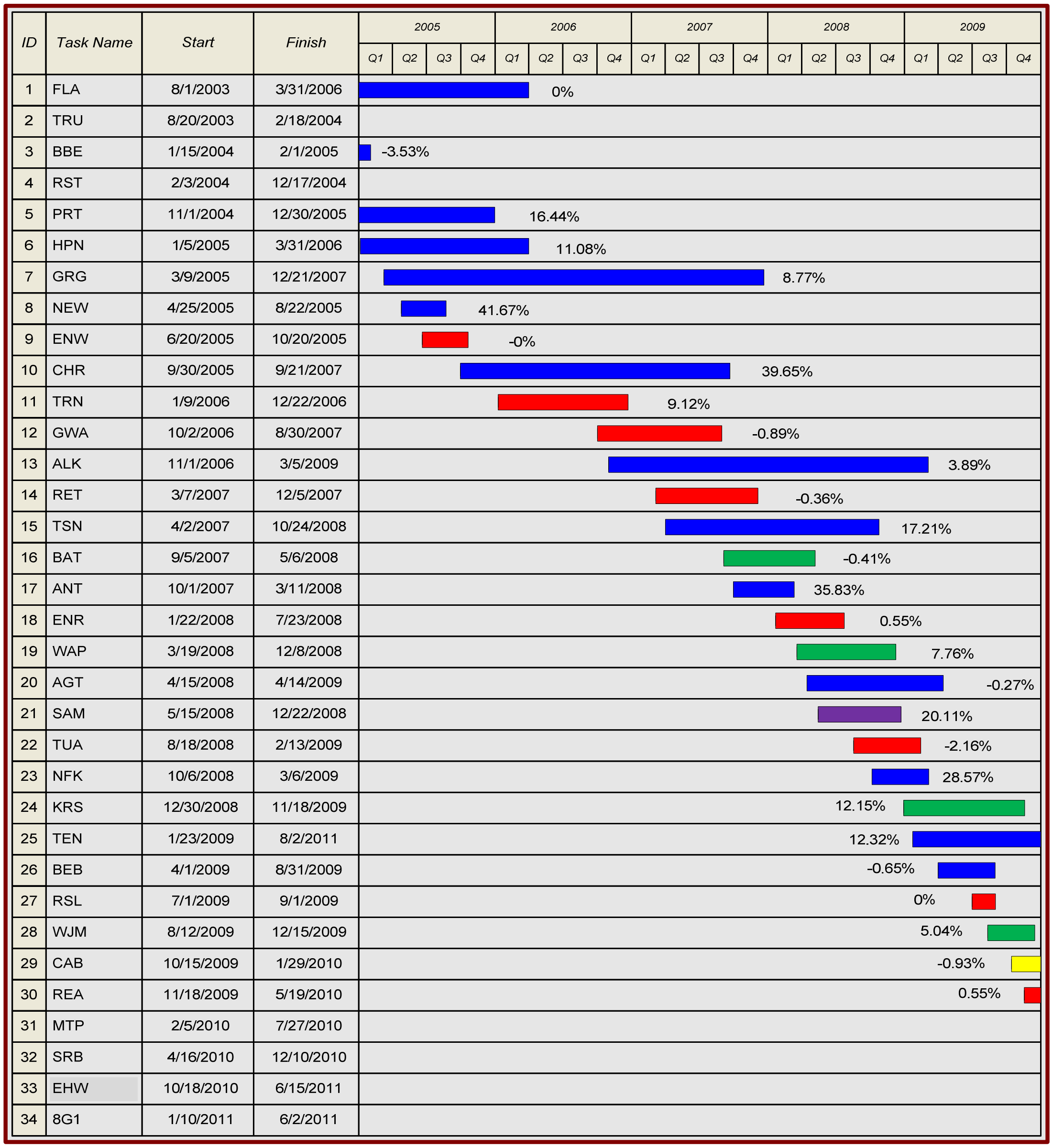

Figure 10. Availabilities in Norfolk Naval Shipyard between 2005 and 2009

In Figure 10, the blue bars represent submarine availabilities, the red represent carrier availabilities, the green represent LHD availabilities, the purple represent MTS availabilities, and the yellow represents an AS availability. The start and finish dates of the corresponding availabilities are given in the columns labeled 'Start' and 'Finish.' Even though data for availabilities starting as early as 2003 and ending as late as 2011 are available, the time range of 2005 to 2009 is studied to ensure all the availabilities that occurred during those years are included.

There are certain time periods where more projects are underway than in others. Using the Gantt chart of Norfolk in Figure 10, one can see that there were only three projects underway in Quarters 2 and 3 of 2006 whereas in Quarters 2 and 3 of 2007 there are six and in Quarters 1 and 2 of 2008 there were as many as eight projects underway. To study possible associations between availability lateness and the number of ongoing projects, the number of availabilities that were underway is counted in the shipyard each year from 2005 to 2009. It is assumed that an availability that is underway for a minimum of 3 months during a year may have an impact on other availabilities being conducted during that year. Thus, if an availability ended in February of 2005 as in the case of the depot modernization period for the USS Boise (BBE), it was not counted towards the total number of availabilities underway in 2005. The next step averages the days late as a percentage of the planned length of the availability of the availabilities that were underway for at least 3 months for each year. The percentage figures next to each color coded bar in the Gantt chart above represent the days late as a percentage of the planned length of the availability. As an example using the Norfolk Gantt chart displayed in Figure 10, seven total availabilities were counted for 2005: FLA, PRT, HPN, GRG, NEW, ENW, and CHR. Their corresponding days late percentages are then averaged, as displayed in Equation 4.

$$\frac{0\% + 16.44\% + 11.08\% + 8.77\% + 41.47\% + 0\% + 39.65\%}{7\,Availabilities} = 16.8\%$$

Equation 4. Sample Calculation of Mean Days Late Percentage for Availabilities Underway Simultaneously in a Shipyard

Table 14 displays the percentage of availabilities that are late as well as the average number of days late as a percentage of scheduled availability length (Mean Days Late %) for the years 2005 to 2009 for each of the four shipyards.

Norfolk					
	Number of Availabilities	**Mean Length**	**% Late**	**Mean Days Late %**	**Std Error**
2005	7	486.1	85.70%	16.80%	14.10%
2006	6	581	66.70%	11.30%	12.90%
2007	8	467.3	62.50%	13.00%	11.90%
2008	9	315.1	66.70%	8.40%	9.20%
2009	7	301.2	50.00%	4.00%	7.40%

Pearl Harbor					
	Number of Availabilities	**Mean Length**	**% Late**	**Mean Days Late %**	**Std Error**
2005	5	291	100.00%	60.70%	21.80%
2006	6	387.5	83.30%	27.60%	18.20%
2007	3	451.7	66.70%	6.20%	13.90%
2008	6	429.7	66.70%	8.70%	11.50%
2009	5	499	80.00%	13.10%	15.10%

Portsmouth					
	Number of Availabilities	**Mean Length**	**% Late**	**Mean Days Late %**	**Std Error**
2005	4	516	100.00%	19.40%	19.80%
2006	5	474.2	100.00%	19.10%	17.60%
2007	6	341.8	100.00%	28.10%	18.30%
2008	7	399.7	100.00%	18.50%	14.70%
2009	6	433.5	83.30%	9.50%	12.00%

Puget Sound					
	Number of Availabilities	**Mean Length**	**% Late**	**Mean Days Late %**	**Std Error**
2005	4	797.3	25.00%	0.80%	4.60%
2006	7	445.6	57.10%	19.50%	15.00%
2007	7	422.1	57.10%	12.70%	12.60%
2008	7	505.9	28.60%	3.10%	6.60%
2009	4	478.5	25.00%	4.60%	10.50%

Table 14. Days Late Percentage Statistics with Various Amounts of Availabilities Underway in the Shipyard

The summary statistics in Table 14 suggest no clear association between the number of availabilities underway in the yard and the mean days-late percentage. In the case of Portsmouth, there are six availabilities underway for a majority of 2007 and 2009, but the mean of the days-late percentages are 28.1% and 9.5%, respectively. For Portsmouth, there does not seem to be much difference between the days late percentage of those availabilities in 2005 when only four are underway and those in 2008 when seven are underway. Figure 11 displays data from Table 14.

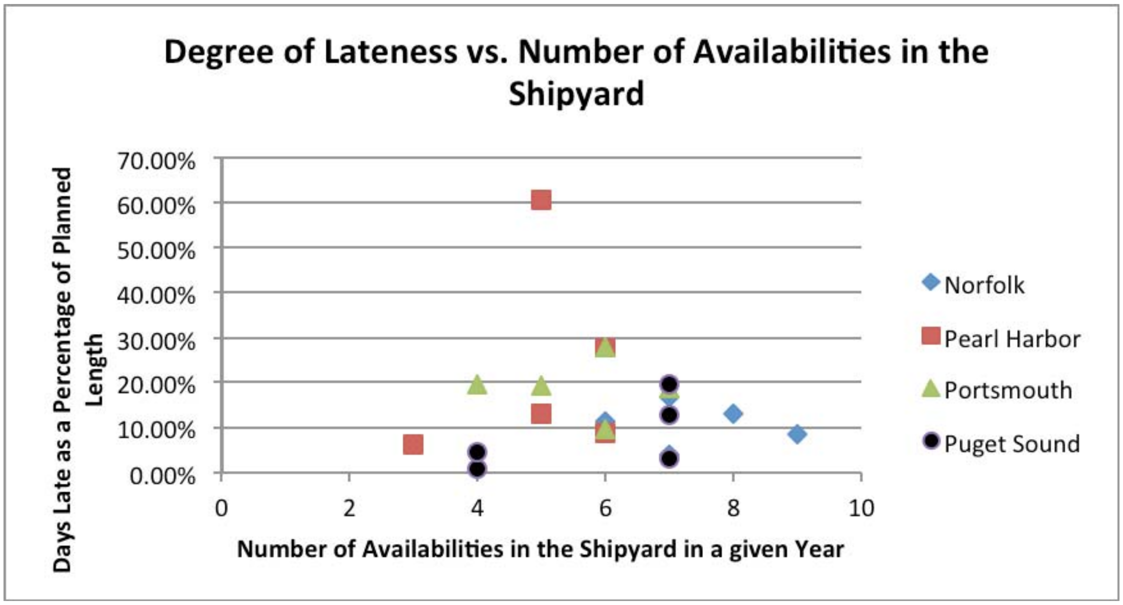

Figure 11. Days Late Percentage as a Function of the Number of Availabilities Underway in the Shipyard

The data displayed in Figure 11 does not suggest a simple relationship between the percentage of days late and the number of availabilities in the yard. The greatest days late percentage for Pearl Harbor occurs with five availabilities underway simultaneously as compared to four or six. The greatest percentage of days late for Norfolk occurs with seven availabilities in the yard as compared to six or nine, and Portsmouth has the greatest percentage of days late with six availabilities in yard as compared to four or seven. Further investigation of any differences between shipyard managerial practices or availability planning methods that may exist with differing numbers of availabilities in the shipyard can lead to increased knowledge of the reasons behind availability lateness. However, taking the standard errors of mean days late percentages into consideration, one can conclude that there is no statistically significant difference between the percentage of days late with regard to the number of availabilities in the shipyard.

Something that stands out from the data summaries displayed in Table 14 is the general improvement in the percentage of days late performance across all the four shipyards from 2005 to 2009. By simply observing the days-late metric across these years, the days late percentage has been decreasing. Figure 12 displays the days-late percentage as a function of year. The dotted lines represent one standard error about the mean for Pearl Harbor and Puget Sound.

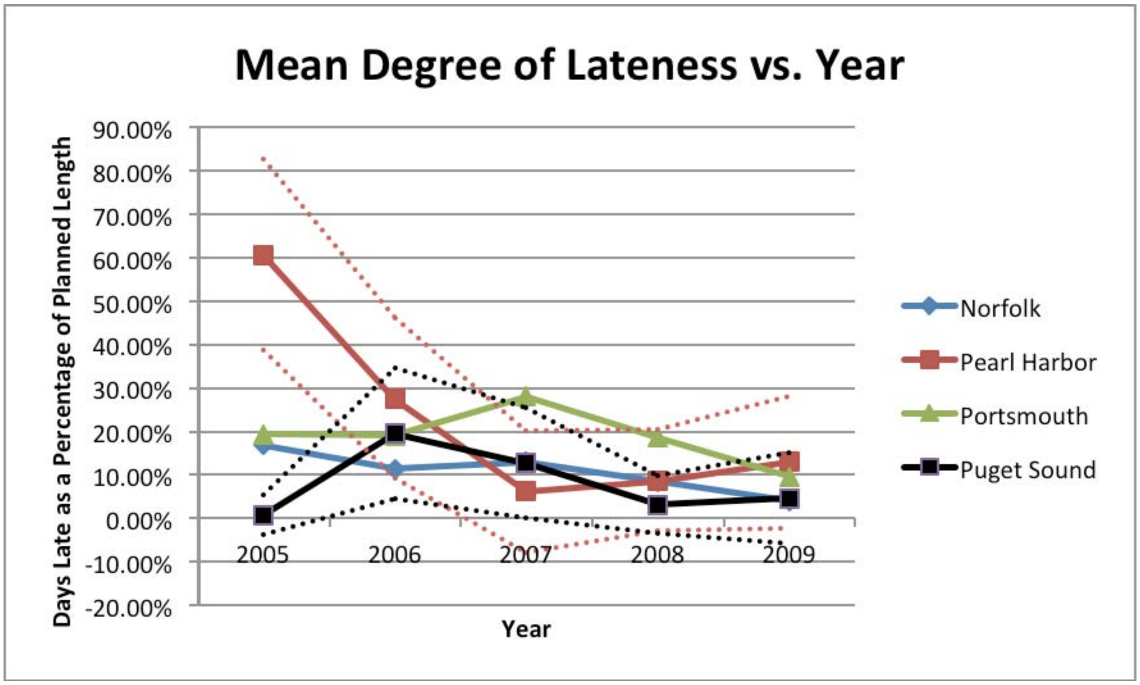

Figure 12. Days Late Percentage Trends from 2005 to 2009

With the exception of 2005, the performance of each shipyard is similar for the years 2006 to 2009. The small number of availabilities considered result in large standard errors for the mean days late percentage; there is no statistically significant difference in the days late percentage between the shipyards between 2006 and 2009. Also, it appears that the mean days late percentage across all shipyards is trending downwards from year to year after 2006. Because of this, it is of interest to see how the days late percentage of availabilities changes from year to year across all shipyards beyond the 2005 to 2009 period. Table 15 displays the mean days-late percentage of all the availabilities that were underway in three separate periods: 2005 and earlier, 2006–2008, and 2009–2010.

	Norfolk		
	2003 to 2005	2006 to 2008	2009 to 2011
# Availabilities	8	14	12
Mean Days Late %	8.10%	9.90%	11.90%
Std Error	5.40%	3.60%	5.70%

	Pearl Harbor		
	2003 to 2005	2006 to 2008	2009 to 2011
# Availabilities	8	9	6
Mean Days Late %	79.20%	16.10%	9.70%
Std Error	24.70%	7.30%	3.90%

	Portsmouth		
	2003 to 2005	2006 to 2008	2009 to 2011
# Availabilities	6	10	5
Mean Days Late %	12.20%	28.60%	7.30%
Std Error	7.40%	8.20%	7.20%

	Puget Sound		
	2002 to 2005	2006 to 2008	2009 to 2011
# Availabilities	8	12	7
Mean Days Late %	10.10%	14.20%	5.10%
Std Error	5.90%	7.10%	3.30%

Table 15. Lateness Statistics over Time

Table 15 displays the number of availabilities underway in each of the associated time periods, along with the mean days late as a percentage of planned length and associated standard errors for those availabilities. For an availability to be associated with the 2003 to 2005 time period, a majority of the availability had to take place in that time period. For example, if an availability spanned from May of 2005 until March of 2006, it was associated with the 2003 to 2005 time period because the availability took place for eight months in 2005 and only 3 months in 2006. Figure 13 displays the data in the Table 15.

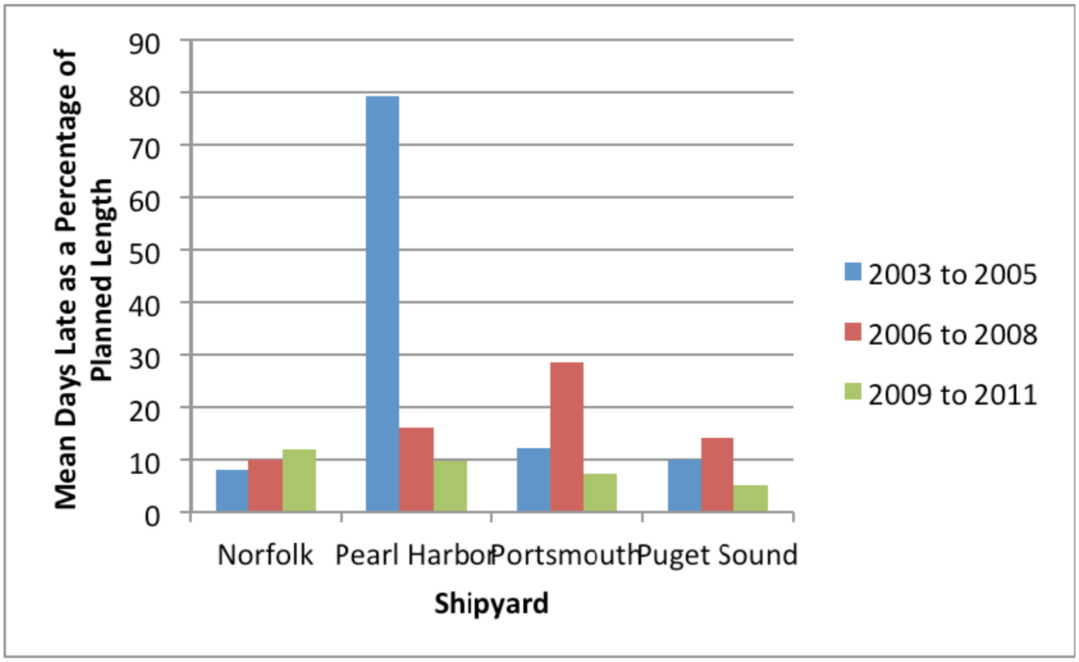

Figure 13. Days Late Percentage Trends from 2003 to 2011

It can be seen that Pearl Harbor shows a continual improvement in the percentage of days late of its availabilities over the three time periods, whereas Norfolk shows a nearly consistent percentage of days late. Even if one availability skews the mean percentage values, as in the case of Norfolk's performance in 2009 through 2011 where one availability conducted on an MTS with a percentage of days late of 62% skewed the average higher, the assumption that all availabilities within a shipyard are interdependent means that the averages properly reflect the performance of the shipyards during that time period. Since Portsmouth and Puget Sound also show improvement in 2009 through 2011 over the 2006 through 2008 periods; although with large associated standard errors, it is possible that the mean percentage of days late of availabilities in general have been decreasing after 2006.

G. EFFECTS OF WINTER MONTHS ON AVAILABILITY LATENESS

In this subsection, associations between the times of year an availability is conducted in Puget Sound and Portsmouth and the number of days late is investigated; in particular it is of interest to investigate possible associations between average percentage of days late and number of months an availability is conducted during the winter months for Puget Sound and Portsmouth. For completed availabilities dating back to 2002, the amount of time the availability is conducted in the winter months as a percentage of the entire length of the availability is calculated and then plotted against the availability's associated days late as a percentage of planned length. The initial hypothesis is that the greater the percentage of time conducted during the winter months, the greater the number of days late as a percentage of the availability length. The months associated with the most extreme weather in Portsmouth are assumed to be December through April because this is the time period when the Portsmouth, New Hampshire/Kittery, Maine area would typically experience the most snowfall (8–12 inches per month December through March) and rainfall (over 9 inches in April, which is 2–3 times more than any other month during the year). The months associated with the most extreme weather in Puget Sound are assumed to be November through March. The Bremerton, Washington area does not typically experience great amounts of snowfall, however it is during these months where there is the greatest amounts of rainfall as compared to the rest of the year. Figure 14 and 15 display the results obtained for submarine availabilities.

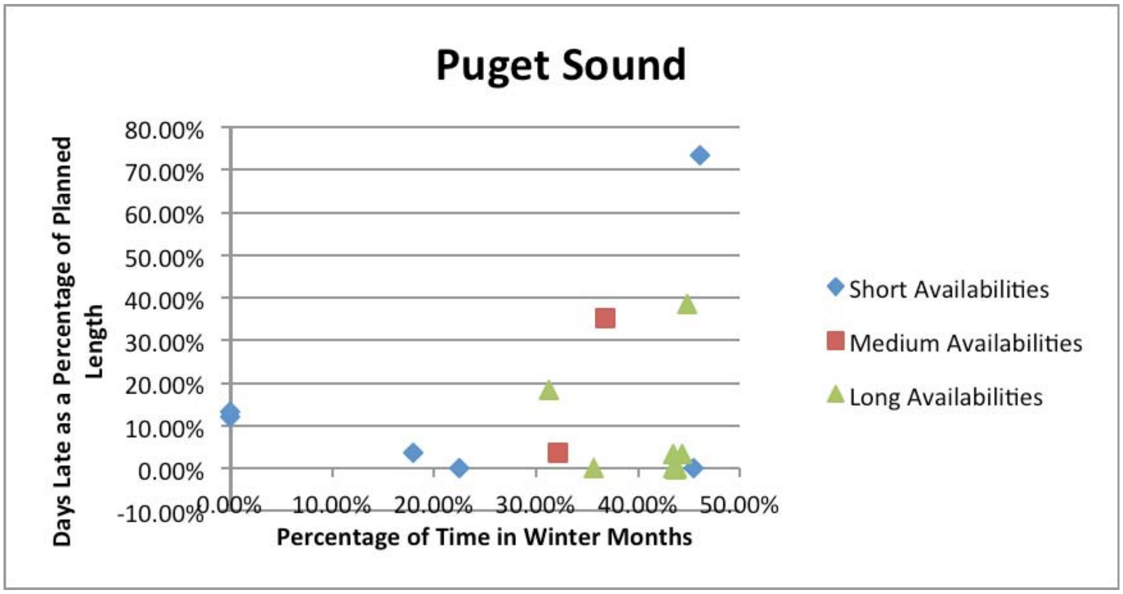

Figure 14. Days Late Percentage as a Function of Percentage of Availability Duration in Inclement Weather Months at Puget Sound Naval Shipyard

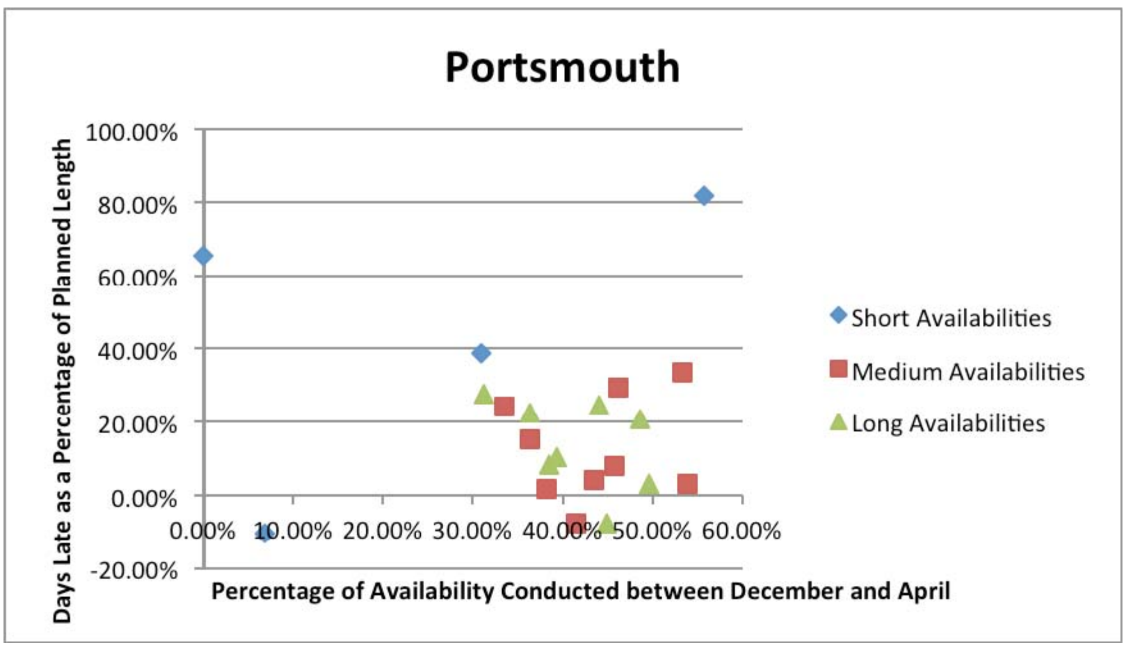

Figure 15. Days Late Percentage as a Function of Percentage of Availability Duration in Inclement Weather Months at Portsmouth Naval Shipyard

In the case of Puget Sound, there may be some association between the amount of time spent in the winter months and the number of days late as a percentage of availability length. 25% of the availabilities with 30% to 40% of time conducted in the winter months had a days late percentage of 20% or more. Over 28% of the availabilities (2 of 7) with a 40% to 50% percentage of time conducted in winter had a days late percentage of 20% or more. Also, of all the availabilities where less than 30% of time was spent during the winter months, none had greater than 20% days late as a percentage of planned length. In the case of Portsmouth, there does not seem to be as clear an association between the amount of time an availability is conducted in the winter months and the days late percentage. Portsmouth has an example of an availability with no time spent in the winter months but still having a number of days late that is roughly 65% the length of the original planned length.

H. IMPACT OF CARRIER AVAILABILITIES ON SUBMARINE AVAILABILITIES

It has been speculated among subject-matter experts that carrier availabilities take precedence over submarine availabilities when it comes to timely maintenance project completion. This is due to a fewer number of carriers and the fact that carrier maintenance can impact the operational schedules of entire carrier battle groups. A hypothesis is that carrier availabilities may draw on manpower resources available from submarine availabilities in order to ensure timely completion. If this is the case, it would be interesting to study on a case by case basis the days late percentage of a submarine availability as a function of the number of carrier availabilities underway during the submarine's availability schedule. Data from fifteen submarine availabilities at Puget Sound are examined to determine the duration that either one or two other carrier availabilities were underway as a percentage of the total length of the submarine availability. For example, if a submarine availability lasts 200 days, and during 30 days of that time period two other carrier availabilities were being conducted and during 100 days only one other carrier availability was being conducted, then for 15% of the availability (30/200) two other carrier projects were being conducted and for 50% of the availability (100/200) only one other carrier project was being conducted. Each of the fifteen submarine availabilities are assigned a carrier impact factor which was calculated by multiplying 2 by the percentage of time that two carriers availabilities were underway during the submarine's availability and adding to that the percentage of time that only one carrier was underway during the submarine's availability. Equation 5 displays the calculation for this example.

$$(2x15\%) + (50\%) = 80 \text{ Carrier Impact Factor}$$

Equation 5. Sample Calculation for Carrier Impact Factor

The carrier impact factor for each availability is then compared to the submarine availability's number of days late as a percentage of planned availability length to investigate whether a larger carrier impact factor would result in a larger days late percentage. Table 16 and Figure 16 display the carrier impact factors and corresponding percentage of days late as a percentage of planned length for the submarine availabilities that occurred in Puget Sound shipyard between 2001 and 2011.

Puget Sound Naval Shipyard				
Availability	End Date	Planned Length (Days)	Carrier Impact Factor	Days Late Percentage
USS HOUSTON (SSN 713)	7/8/04	730	48.1	38.49%
USS OHIO (SSGN 726)	12/23/05	1096	72.7	3.47%
USS JEFFERSON CITY (SSN 759)	8/1/04	394	91.2	35.28%
USS MICHIGAN (SSGN 727)	12/6/06	996	81.6	0.00%
USS COLUMBUS (SSN 762)	12/16/06	760	82.1	-0.13%
USS ALABAMA (SSBN 731)	5/16/08	821	100.2	3.41%
USS HELENA (SSN 725)	5/27/06	60	83.7	73.33%
USS TOPEKA (SSN 754)	11/20/06	107	98.2	3.74%
USS HONOLULU (SSN 718)	11/30/08	760	102.2	0.00%
USS SAN FRANCISCO (SSN 711)	4/14/09	727	99.6	18.43%
USS ASHEVILLE (SSN 758)	9/11/07	91	129.3	12.09%
USS NEVADA (SSBN 733)	5/7/10	820	78	0.00%
USS JIMMY CARTER (SSN 23)	7/3/08	120	34.2	0.00%
USS JEFFERSON CITY (SSN 759)	12/20/08	110	100	0.00%
USS JIMMY CARTER (SSN 23)	12/23/10	303	87.3	3.63%

Table 16. Carrier Impact Factors and Submarine Availability Lateness Statistics at Puget Sound Naval Shipyard

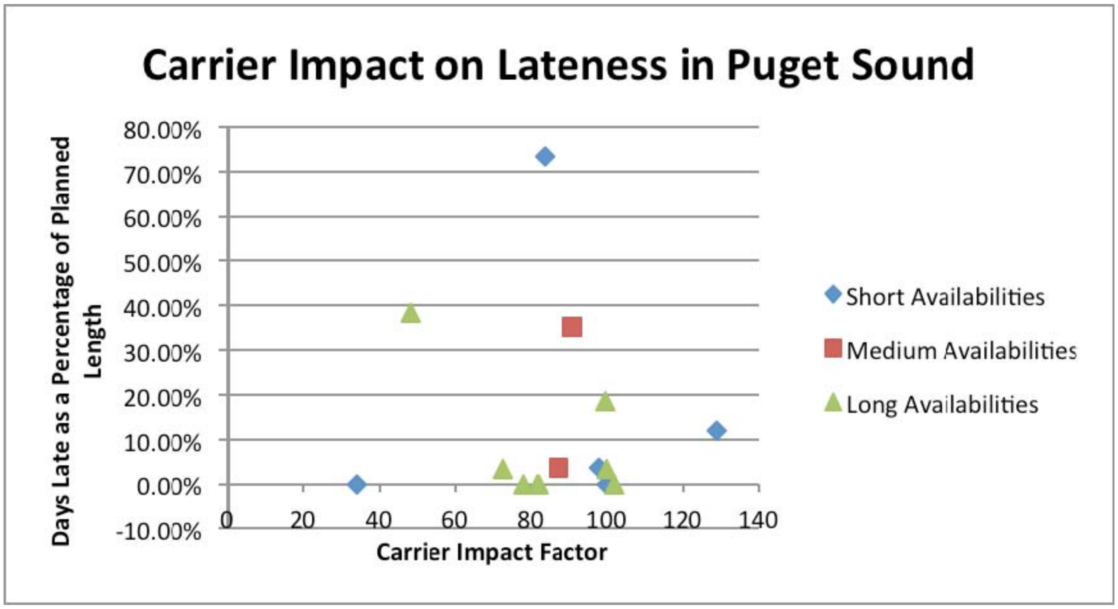

Figure 16. Days Late Percentage as a Function of Carrier Impact Factor

This plot does not provide clear evidence that carrier availabilities have a direct association with the lateness of submarine availabilities based on fifteen data samples. Further investigation can include a similar study of the submarine availabilities at Norfolk Naval Shipyard. Pearl Harbor and Portsmouth shipyards do not conduct carrier availabilities. Figure 17 displays the carrier impact factor as a function of availability length, which demonstrates clearly that longer availabilities do not have a tendency to negatively impact carrier availabilities.

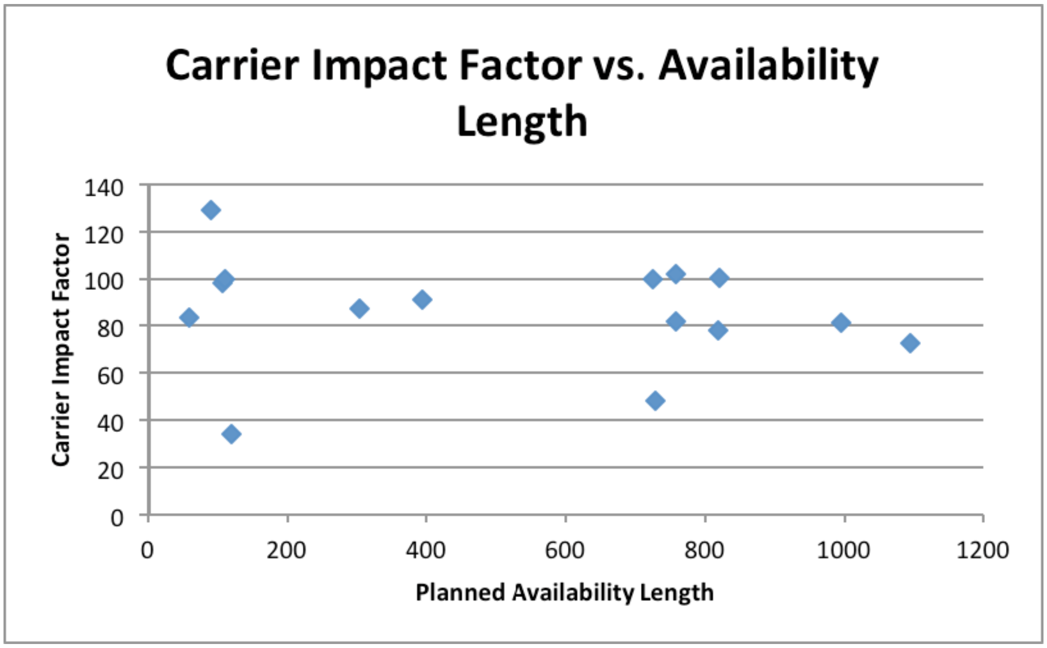

Figure 17. Carrier Impact Factor as a Function of Planned Availability Length

I. IMPACT OF PERSONNEL RESOURCES ON AVAILABILITY LATENESS

In this subsection, the relationship between the number of personnel resources available to work on an availability (measured in average man-days per month), with availability lateness is studied. The data provide values for BQWP, AQWP, availability start dates, availability end dates, and finally, the number of days the availability completes late. Two estimates are calculated for comparison: the planned number of man-days required to complete the work for each availability per month (BQWP/mo) and the actual number of man-days charged to each availability per month (AQWP/mo). The estimated planned number of man-days per month is calculated by dividing the BQWP by the planned availability length in months. The estimated actual number of man-days is calculated by dividing AQWP by the actual availability length in months. To determine actual availability lengths, the number of days between availability start and end is calculated and then divided by 30.42, which is the average number of days per month over a given year (365/12 = 30.42). Planned availability length is calculated as the number of actual days between start and end minus the number of days late and divided by 30.42; the values obtained for actual and budgeted man-days per month are simply estimated averages over the availabilities of interest of the actual and planned man-days charged and earned on a monthly basis.

Table 17 displays the mean number of man-days per month for late submarine availabilities and for on-schedule submarine availabilities; also displayed are the means for late carrier availabilities and on-schedule carrier availabilities.

	Submarines	
	Late Availabilities	On-Schedule Availabilities
Mean AQWP/Mo	11076.6	11778.57
Mean BQWP/Mo	11826.05	10634.39
Difference	-749.45	1144.18
% Difference	-6.34%	10.76%
Count	56	19

	Carriers	
	Late Availabilities	On-Schedule Availabilities
Mean AQWP/Mo	27588.05	21813.46
Mean BQWP/Mo	28675.38	21464.38
Difference	-1087.33	349.08
% Difference	-3.79%	1.63%
Count	8	16

Table 17. AQWP per Month and BQWP per Month Statistics for Late and Timely Availabilities

The rows labeled 'difference' display the difference between AQWP per month and BQWP per month for both late availabilities and on-schedule availabilities. The row labeled '% difference' is 'difference' as a percentage of 'mean BQWP/Mo.' The complete t-test data summaries are displayed in Appendix B. For both carriers and submarines, late availabilities on average charge less in man-days per month than the amount of man-days planned to complete the work. This possibly indicates an insufficient commitment of resources to the availability or an inflated BQWP that changed due to the addition of initially unexpected new work. As can be seen, the mean

BQWP per month for timely availabilities of both carriers and submarines tends to be less than the mean BQWP per month for late availabilities. Also important to note is that the charged amount of work per month for timely availabilities tends to exceed the planned amount of work per month, possibly indicating a commitment of a greater magnitude of resources to the project to ensure timeliness. To investigate further, late and on-schedule availabilities were broken down by availability type to ensure that similar availabilities are being compared.

	Submarine DSRA (SSN)	
	Late Availabilities	On-Schedule Availabilities
Mean AQWP/Mo	9532.91	10848.72
Mean BQWP/Mo	11645.66	9981.85
Difference	-2112.75	866.87
% Difference	-18.14%	8.68%
Num Avails	20	7

	Submarine DMP (SSN)	
	Late Availabilities	On-Schedule Availabilities
Mean AQWP/Mo	12913.11	13508.13
Mean BQWP/Mo	13332.12	11280.08
Difference	-419.01	2228.05
% Difference	-3.14%	19.75%
Num Avails	10	3

	Submarine IA (SSN)	
	Late Availabilities	On-Schedule Availabilities
Mean AQWP/Mo	4870.07	5102.19
Mean BQWP/Mo	4859.24	4571.23
Difference	10.83	530.96
% Difference	0.22%	11.62%
Num Avails	3	3

	Submarine ERO (SSBN/SSGN)	
	Late Availabilities	On-Schedule Availabilities
Mean AQWP/Mo	15490.3	15216.44
Mean BQWP/Mo	14579.41	14309.07
Difference	910.89	907.37
% Difference	6.25%	6.34%
Num Avails	4	3

Table 18. AQWP per Month and BQWP per Month Statistics for Various Availability Types

	CARRIER PIA (CVN)	
	Late Availabilities	On-Schedule Availabilities
Mean AQWP/Mo	27889.65	23211.27
Mean BQWP/Mo	29932.22	23146.75
Difference	-2042.57	64.52
% Difference	-6.82%	0.28%
Num Avails	5	10

Table 19. AQWP per Month and BQWP per Month Statistics for Various Availability Types

The statistics in Table 19 (standard errors of the means are displayed in Appendix C) suggest that for all availability types, the mean AQWP per month tends to exceed the planned BQWP per month for timely availabilities. The statistics also suggest that for all availability types, with the exception of SSBN/SSGN engineering overhauls and SSN inactivation activities, the mean AQWP per month tends to be less than the planned BQWP per month for late availabilities, although the figures for overhauls and IAs are similar. Additionally, for all availability types, the average amount of resources needed to complete the work as represented by BQWP per month tends to be greater for late availabilities than timely availabilities.

Taking on a different perspective will shed some light on the amount of personnel resources needed on a monthly basis to ensure a timely availability. In this summary, both the AQWP and BQWP of the availability are divided by the planned availability length in months. If the actual quantity of work performed is divided by the planned length, this can give an indication of the amount of work that would have been required on a monthly basis to finish the availability by the planned end date. Table 20 displays the results.

	Submarines	
	Late Availabilities	On-Schedule Availabilities
Mean AQWP	14045.9	11493.6
Mean BQWP	11826.1	10634.4
Difference	2219.8	859.2
% Difference	18.77%	8.08%
Count	56	19

	Carriers	
	Late Availabilities	On-Schedule Availabilities
Mean AQWP	31702.5	21727.4
Mean BQWP	28675.4	21464.4
Difference	3027.1	263
% Difference	10.56%	1.23%
Count	8	16

Table 20. AQWP and BQWP divided by Planned Availability Length in Months

For both late submarine and carrier availabilities, the actual average quantity of work performed per month is greater than the budgeted quantity of work performed per month by roughly 18% and 10% of the planned work, respectively. The on-schedule availabilities show a closer match between the man-days charged on a monthly basis and the planned number of monthly man-days needed. In conclusion, the monthly average man-days required to complete the availability tends to be greater than the planned monthly average by a larger amount for late availabilities than for timely availabilities.

J. SUMMARY

Shipyard performance data are summarized and displayed in various ways to gain insight into possible reasons contributing to availability lateness. The study is limited to data on 108 completed availabilities, resulting in a limited ability to produce statistically significant conclusions. The sections to follow analyze the impacts of a factor not yet covered in this study: work stoppages.

IV. AVAILABILITY EXECUTION

A. INTRODUCTION

This chapter summarizes the theory on network scheduling, describes work stoppages, and provides background information on availability execution processes. The intent of this chapter is to describe how work stoppages influence the execution of an availability.

B. NETWORK SCHEDULING

Shipyard project managers continually track and update all in-progress jobs during an ongoing availability, with the goal of finishing the availability on time. The scheduling (planning phase) and maintaining (execution phase) of the Availability Work Package (AWP, discussed in Chapter II) jobs is one of the most important activities to accomplish in the determination of how an availability's resources should be integrated, especially when multiple jobs during a single availability are executing in parallel (Kerzner 2009). Due to the high complexity of the AWP and tight schedule deadlines, project managers are challenged to solve problems rapidly, efficiently, and with minimal impact to separate on-going jobs. As a result, scheduling techniques have been developed which allow project managers to mitigate the effects of unplanned events that arise during availability execution. Network modeling and critical path analysis are essential for project managers to understand in order to reveal the interdependencies between the on-going jobs and to help managers evaluate alternatives by answering questions such as how time delays will affect the availability's completion (2009).

1. Network Fundamentals

A project is composed of a series of activities, determined by the management team, and constructed in such a way to achieve a desired objective (Blanchard and Fabrycky 2011). A network diagram is a pictorial representation of the events and activities that must be accomplished for a project to be deemed complete. Applying this definition and terminology to a CNO availability, events are the major milestones of the availability, for example, start availability (denoted SA00), complete undocking (denoted

UD00), and complete availability (denoted CA00). Network activities are the work package jobs, for example, engine clean and inspection, compartment painting, and fire pump maintenance. The construction of a network diagram allows the availability's management team to identify all interdependencies that are present between events and activities (Kerzner 2009).

As seen in Figure 18 of a network diagram, each activity consumes time and is represented by a single box. Activities are linked in a precedential order in order to show which activities must be finished before others can start. The arrows show activity precedence, and an activity is unable to start until all prior activities linked to it by the arrows are finished (2009). Each box is assigned a unique activity number, located at the lower left hand corner, which signifies precedence level.

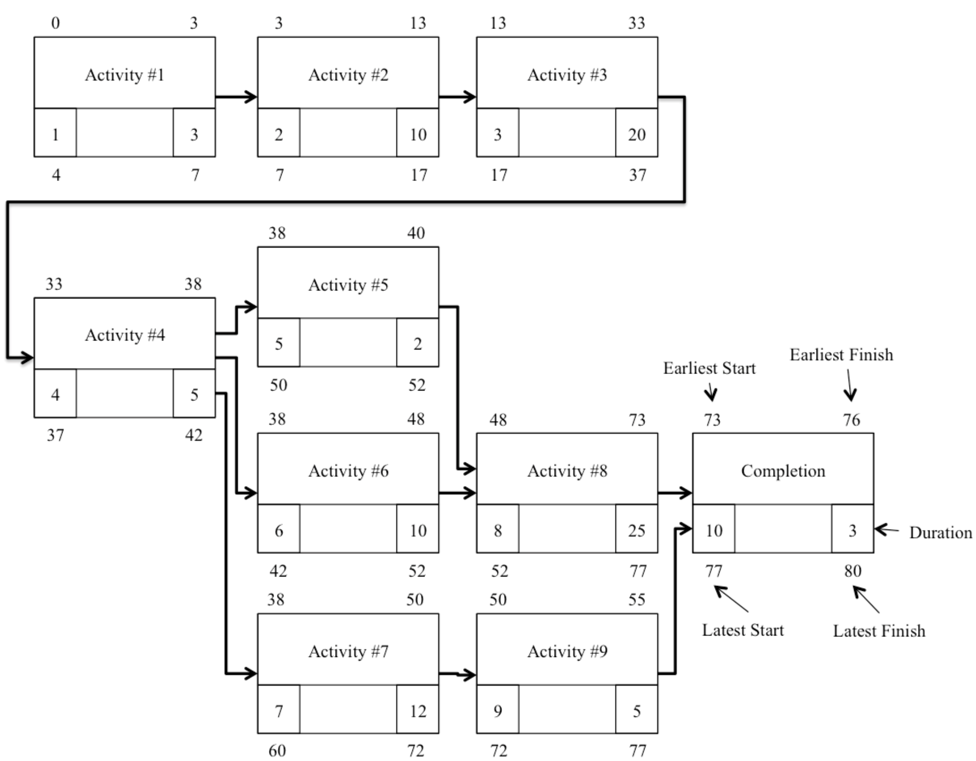

Figure 18. Network Diagram Example (After Langford 2011)

All activities are assigned durations by estimating how long each activity will take, to include the time for all work to be completed plus preparation and waiting time. Realistic durations are essential to developing a credible, executable availability schedule. Work package job durations must be determined in a judicious, carefully considered manner. Job duration estimation reflects the manner in which the work will be performed as well as the historical performance of similar work ("Baseline Project Management Plan," NAVSEA 07, 2009). The next step after duration estimation is to calculate the project schedule that provides the earliest and latest times at which each activity can start and finish. The earliest start time for an activity is based on the projected estimated start time and the duration estimation for preceding activities. Likewise, the earliest finish time is calculated by adding the given activity's duration to the activity's earliest start time (Kerzner 2009). The latest start and finish times is a backwards calculation, starting from the completion date, with the intention of determining the latest time at which an activity can take place without extending the completion date of the project (2009). The difference between the scheduled completion date and the total duration date is known as the slack time, commonly referred to as "float" in the Naval project management community.

a. Float

Float is an important measurement that allows an availability's management team to determine how early or late an activity can start or finish. Float, as mentioned earlier, is the difference between the latest finish date and the earliest finish date. This difference will indicate whether the project will need to be accelerated or not, based on the three types of float, described as follows:

- Positive float is the maximum amount of time the activities on the critical path can be delayed without jeopardizing the project's completion date.
- Negative float is the amount of time the activities on the critical path must be accelerated in order to meet the project's completion date.
- Zero float means the critical path does not need to be accelerated, nor can it be delayed (Langford 2011).

Float during a CNO availability is calculated on multiple levels: each job, each important milestone, and the availability completion's float are all calculated. Negative float occurs when the planned or actual duration of the project extends beyond the planned end date. Negative float during the planning phase of an availability may signify an unreasonable amount of work is scheduled for the time allotted. Positive float experienced during the planning phase but negative float experienced during the execution phase can be attributed to job duration estimations and planned completion dates being highly optimistic and unrealistic (Kerzner 2009). NAVSEA currently directs all availability planning teams to add 30 extra days to the availability completion date to ensure that positive float is maintained during the availability's execution ("AIM-NG Process Manual," NAVSEA 04X, 2009).

2. Scheduling Problems

Problems arise during the execution of all availabilities that can impact the schedule by decreasing the amount of float. Scheduling problems include (but are not limited to) using unrealistic estimates for job durations, lack of personnel with requisite skills, over committing resources and having to share critical resources across several projects, frequent revisions to the primary work schedule, and unforeseen bottlenecks (Kerzner 2009). An availability work stoppage is a type of schedule problem and it is the primary factor that this research considers. The Theory of Constraints, which is a schedule improvement methodology discussed in the next section is applied to the availability work stoppage data in order to identify the impact on schedules due to work stoppages.

C. THEORY OF CONSTRAINTS

The Theory of Constraints (TOC) is the management technique, introduced by Eliyahu M. Goldratt, which seeks to improve the process of planning and execution. In Thomas B. McMullen's 1998 book, *Introduction to the Theory of Constraints Management System*, he states, "the Theory of Constraints always ask, 'What must something be if, in its category, it is inevitably to be the best that can be?'" TOC is applied using the proposed five-step process:

1. Identify the system's constraints.
2. Decide how to exploit the constraints.
3. Fully support the decision by means of policies, processes, and resources.
4. Remove the identified constraints.
5. Return to Step 1.

McMullen further discusses that regardless of the system, to which TOC is being applied, it is assumed that in order for TOC to be effective, the system must have a goal. The goal of the system has three requirements: its owners must determine the goal; it must be measureable; and it is subject to necessary conditions. In the case of a shipyard availability, the owners are the stakeholders, which include the availability's planning and execution teams, the shipyard's leadership, and NAVSEA. The measureable goal is to maintain and stay-on schedule. The third requirement, necessary conditions, is the procedures and laws of the shipyard that ensure the continuing operation of the availability. Examples of conditions include the shipyard safety requirements, technician qualifications, and workmanship quality. The primary goal of NAVSEA with respect to maintenance activities, regardless of system application, is in developing, delivering, and maintaining ships and systems on time and on cost for the United States Navy. Within the scope of TOC and this thesis, the NAVSEA goals, according to NAVSEA's *Strategic Business Plan for 2009–2013*, are identified as follows:

- Develop annual balanced, optimized, and integrated Maintenance and Modernization Execution Plans for shipyards.
- Execute the Maintenance and Modernization Execution Plan and assess the results using metrics.

Based on these specified NAVSEA goals, this thesis' work stoppage analysis assumes that the primary goal of a shipyard availability is to complete the AWP on time, according to the planned schedule. This goal is applied to the availability as a whole and also to individual jobs themselves. It is further assumed that work stoppages are the TOC quantitative measurements used to determine a schedule constraint.

A constraint is defined as anything that blocks the system from accomplishing its goal (McMullen 1998). During the execution phase of an availability, work package jobs are started as dictated by the project schedule and the project manager. Once the job is started, it is classified as an active job and it is assumed that the job will finish on time and in the correct manner. If during the execution of an active job, a constraint is identified which prevents the job from being accomplished on schedule, a work stoppage is activated. The work stoppage is not closed until the constraint is resolved and work on the job is resumed. Constraints are organized into two categories: physical and policy. Physical constraints are classified as "scarce resources" whereas a policy constraint contains all other types of constraints. Work stoppages are classified based on eight categories, known as reasons. Table 20 organizes the work stoppage reasons by constraint type (1998):

Physical Constraint	**Policy Constraint**
Material	Technical Direction
Labor Resources	Work Control
Tooling	Workmanship/Rework
	Interference/Coordination
	Safety

Table 21. Work Stoppage Reasons Organized Based on Constraint Type

1. Critical Chain Management

Critical chain management is a methodology that addresses the need to get each project completed quickly and funnel more projects through the organization without additional resources (Kerzner 2009). A critical chain is defined as the longest chain of dependent events and/or activities where the dependency is either task or resource related. It is assumed from this definition that the longest chain of a project is most likely to negatively impact the overall duration of a project (2009). Stepping back to network fundamentals, a project's network diagram is composed of activities in multiple parallel and series configurations, being executed simultaneously; all the paths of activities need to be completed according to the schedule. Project managers rely on critical chain management to prioritize jobs and focus on the most crucial path of activities to be completed. The critical chain is the most time consuming path of activities during execution and is depicted as the longest path of activities in the network diagram; an example is displayed in Figure 19.

TOC is used to specify the critical path (chain) of sequential jobs whose late completion most adversely affects the timely completion of the availability. The NAVSEA WebAIM-NG software assists the availability's project manager in managing unexpected delays, in order to keep the critical path's work progressing.

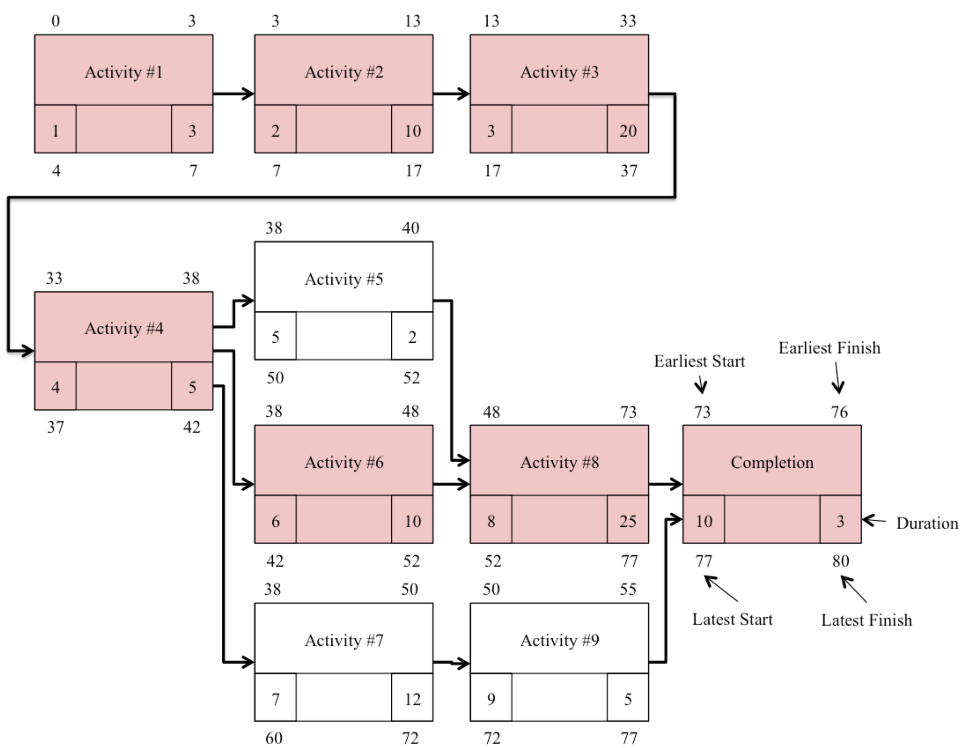

Figure 19. Critical Chain Colored in Red (After Langford 2011)

D. WORK STOPPAGE

The term "work stoppage" is defined as a delay experienced by a job during the execution phase of the availability. Specifically, a work stoppage occurs when work on a job is delayed by more than one shift ("AIM-NG Process Manual," NAVSEA 04X, 2009). Work stoppages are categorized into eight reason codes (RSN):

- Technical Direction (TD)–awaiting engineering resolution or technical direction (i.e., NAVSEA approved instructions) for work continuation.
- Material (MAT)–delay in obtaining/receiving material.
- Tooling (TL)–delay due to limited quantity of tools and manufacturing support of new special tooling.
- Labor Resources (RSC)–shortage of manpower and other support services.
- Work Control (WC)–administrative controls over system conditions needed to ensure safe work conditions are met prior to start of work
- Workmanship/Rework (W)–delay due to rework
- Interference/Coordination (IC)–delay due to multi-job priority levels, often due to space constraints and conditions.
- Safety (SAF) –delay due to shipyard safety violation

E. WEB AIM-NG SOFTWARE

WebAIM-NG software is a project management tool, utilized for both planning and executing an availability, which assists the availability project team in planning, monitoring, and tracking all AWP jobs. This section describes the role of the software in the execution of shipyard availabilities.

1. Execution Priorities

Execution Priorities (EPR), as described in the *AIM-NG Process Manual*, is a logic process within the WebAIM software that develops and establishes shipyard priorities across all projects and availabilities within each shipyard. One of the main objectives of the EPR process is to identify on a daily basis the jobs that must be supported to maintain the non-stop execution of the critical chain in each availability. EPR tracks all activities and analyzes their impacts to the schedule. This is accomplished by evaluating activity durations, resource requirements, network sequencing, and known constraints in order to continually develop a list of priorities to aid the program manager in establishing a path forward. Figure 20 represents the EPR process and describes the required inputs, process logics, and the resulting outcomes. Depending in the daily impacts and the continual evaluation and identification of critical jobs by the EPR, the availability may have a continually changing critical path.

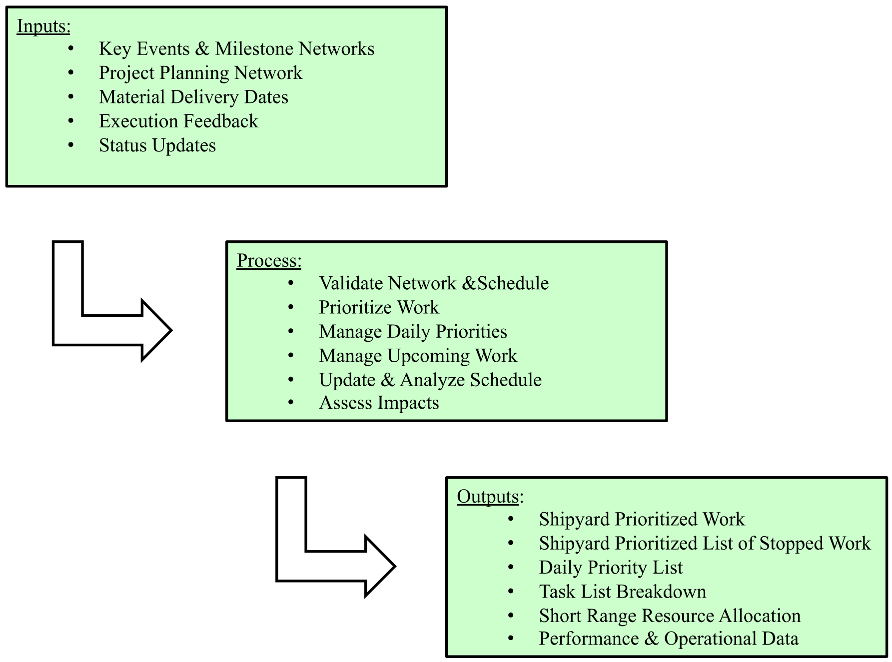

Figure 20. EPR Process Diagram (After NAVSEA 04X 2009)

EPR color-codes all activities in order to bring attention to the critical work, prioritizing based on each activity's float, according to the following:

- Red activities have fewer than 10 shifts of float and are on or near the Critical Chain. Completing Red activities late will likely prevent the project from meeting the key event associated with the activity.
- Yellow activities are the next-most-important selection of activities relative to completing events.
- Green activities more than 30 shifts of float.

The color-coded activities are compiled and distributed into the Daily Priority List (DPL). The DPL lists the activities in priority number order, with the most critical activity needing support first. Availability teams use the DPL on a daily basis to identify the critical problems and develop/implement corrective actions with the goal of ensuring timely completion of work on of the critical chain.

F. SUMMARY

Network models are the framework for the management of the availability execution process. By identifying the interdependencies between project activities, network models allow for the identification of the critical chain. As the longest chain, in terms of completion time, of connecting activities, the time to complete the jobs in the critical chain can impact the overall duration of the entire project. Due to the importance of this crucial chain of activities and the high complexity level of a shipyard availability, shipyards employ the WebAIM-NG software, which aids the availability team in identifying the critical chain and allows the team to support timely work completion of activities on this chain.

V. WORK STOPPAGE ANALYSIS

A. INTRODUCTION

This chapter displays statistical summaries of work stoppage data. The goal of this analytical chapter is to summarize the work stoppage data to display commonalities between availabilities and to investigate possible trends in work stoppages and predictors of availability lateness. In order to identify associations between work stoppages and availability lateness, the analysis assumes that work stoppages are the only reason for schedule delays; no other factors and influences are considered.

B. RAW WORK STOPPAGE DATA

Work stoppage data are provided, in Microsoft Excel format, by SEA 04X. The data are collected from all four public shipyards and include all availabilities in which a work stoppage was submitted. Table 21 provides a sample of the data. The work stoppage data include the following categories (NAVSEA 04X 2009):

- Date – month, year, and day the activity's work stoppage data was queried.
- Shipyard Priority Number (SY Pri) – assigned number to the work stoppage entry based on all ongoing work, across all platforms in shipyard. Priority number directly reflects the urgency of the item regarding its impact on the availability's critical chain
- Project Identification (Proj ID) – three character alphanumeric code to classify availability identity (i.e., 21Q is the USS SEAWOLF Depot Modernization Period).
- Key Event and Milestone (KE/MS) – key event or milestone to which item is directly related to.
- Job Identification Number (JO-KO/SA#) – alphanumeric code to identify specific activity.
- Start and Finish Dates – dates in which the activity started and plans to finish. The finish date is updated to reflect delays.
- Remaining Duration (RDU) – remaining duration until activity is complete. Updated on a daily basis.
- Calendar (Cal) – scheduling code that describes working shifts (i.e., 15 represents one shift per day, five days per week).

Date	SY Pri	Proj ID	KE	MS	JO-KO/SA#	Start	Finish	RDU	Cal	TGI	WKG	Cog Code	RSN	Clr
5/24/10	3594	21Q	UD00	SS01	3621Q02802-A01	05/06/2010	06/02/2010	2	15	REC	WKG	2310	TD	G
6/1/10	3071	21Q	UD00	SS01	3621Q02802-A01	05/06/2010	06/02/2010	2	15	REC	WKG	2310	TD	G
5/24/10	407	SRB	FD00	FD10	36SRB83101-R11	05/26/2010	05/26/2010	3	36	REC	PKG	2305	MAT	R
6/6/11	5324	174	UD00	SS03	3617408008-S09	06/01/2011	07/05/2011	2	15	REC	WKG	2340	IC	G
4/25/11	163	TMN	FD00	FD29	38TMN16303-U43	04/08/2011	05/04/2011	16	25	REC	WKG	c-250	TD	R
7/26/10	86	SRB	FD00	FD42	38SRB17602-A40	07/19/2010	08/06/2010	22	26		WKG	106	SAF	R
1/10/11	18534	WVA	SA00	PRB	38WVA03509-F13	03/10/2011	03/23/2011	10	15	REC	MAT	C-500	MAT	R
10/25/10	1947	174	RM00	MP01	3817463104-U33	10/19/2010	10/28/2010	4	15	REC	WKG	290	TD	G
11/8/10	917	174	RM00	UD57	3817463104-U33	10/19/2010	11/09/2010	3	15	REC	WKG	930	SAF	Y
12/20/10	35016	35N	SS00	SS35	3635N84005-S08	04/12/2010	04/26/2011	2	15		WKG	335	IC	Y
6/20/11	25149	35N	SS00	SS35	3635N84005-S08	04/12/2010	08/03/2011	3	16		WKG	C/335	IC	R
11/1/10	6861	EHW	PW00	PW42	36EHW88406-A03	11/01/2010	11/01/2010	1	15		REL	2340	IC	G
9/6/11	5791	H05	SS00	SS03	36H0582601-M01	07/25/2011	09/21/2011	2	15	REC	WKG	C/2340	WC	G
10/17/11	563	H05	SS00	SS03	36H0584003-M01	08/29/2011	10/26/2011	3	15	REC	WKG	250	MAT	R

Table 22. Sample SEA 04X Work Stoppage Data

- Task Group Instruction Codes (TGI)–Technical Work Document (TWD) statuses.
- Working Status (WKG)–activity status.
- Cog Code–shipyard department responsible for resolving the work stoppage.
- Reason Code (RSN)–eight work stoppage reasons (discussed in chapter IV).
- Color Code (Clr)–identifies activity criticality and impact to the availability's critical chain (discussed in Chapter IV).

The work stoppage data are a weekly look at all active work stoppages for all on-going availabilities. An active work stoppage is one in which a delay has been experienced in an activity and the administrative paper work has been submitted and is not yet resolved. Since work stoppages are continually submitted and cleared (resolved) on a daily basis, the collected work stoppage data does not account for every work stoppage experienced during an availability. This is due to the SEA 04X query rate. SEA 04X conducts a query of the WebAIM software at the beginning of every week, usually every Monday; the results of this weekly query are displayed in the spreadsheet. In addition, the data provided does not give work stoppage submissions and clearing dates, preventing determination of work stoppage duration. Fortunately, duration can be roughly estimated based on the number of concurrent weeks a single work stoppage is observed. For example, if a work stoppage is observed once in the data set, it can be implied that its duration can be at least one day but no longer than 13 days. Similarly, if the same work stoppage, based on matching job numbers and reason codes, is present in the data for two consecutive weeks, then it can be assumed that its duration is at least eight days but no longer than 21 days. As a result of this large range of possible durations, the average of the extremities is assumed to be the work stoppage duration; an entry observed once is assumed to have a work stoppage duration of seven days, or one week. This data is analyzed for the purpose of identifying general trends on significant work stoppage delays.

The data include multiple hull types, shipyard locations, and availability types, and is summarized in Table 22.

Total Number of Availabilities		32	
By Hull Type			
Number of Submarines		24	
Number of Carriers		6	
Number of Moored Training Ships		2	
By Shipyard			
Norfolk Naval		9	
Puget Sound		10	
Pearl Harbor		6	
Portsmouth		7	
By Availability Type			
DSRA	6	DEM	2
EOH	6	IA	2
PIA	3	MMP	1
ERO	3	SRA	1
PIRA	2	DMP	1
RCD	2	CM	1
DPIA	2		

Table 23. High Level Work Stoppage Data Characteristics

1. Description of the Data

The work stoppage data obtained covers approximately 18 months, between 24 May 2010 and 05 December 2011. During that time 32 availabilities had either started, completed, or both. Specifically, 14 availabilities had started prior to the collection window with nine of them finishing before the last collection date; 17 availabilities were still in-progress after the last collection date; and six availabilities had started and completed within the collection window. Figure 21 depicts the availability lengths and the collection window. The thick black box represents the data collection timeframe. The graph is color coded with red representing in-progress availabilities at time of the last data collection date, yellow representing availabilities that started prior to the start of data collection, and green representing availabilities that started and completed inside the data collection timeframe.

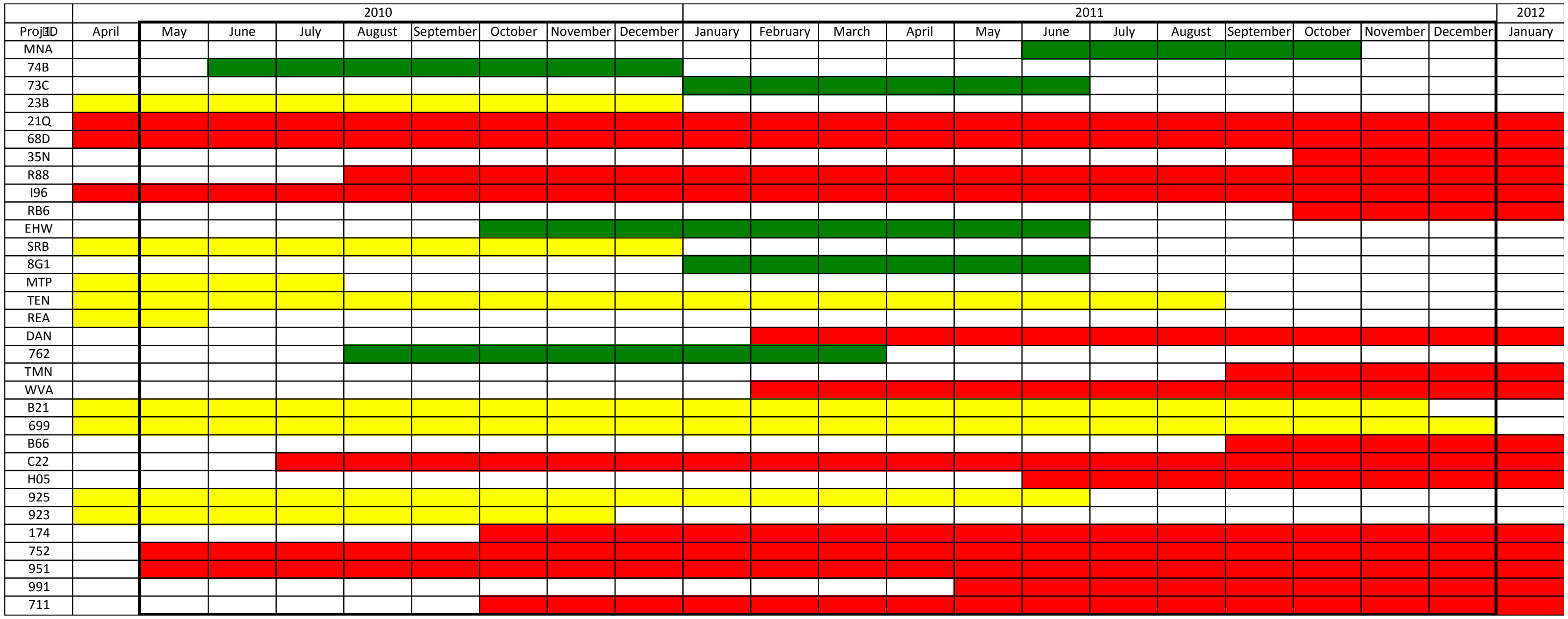

Figure 21. Actual Availability Lengths Compared with Data Collection Timeframe

Of the 32 availabilities, only the six availabilities that started and completed inside the data collection timeframe are used for the analysis of work stoppage. The availabilities that started prior to the collection timeframe are considered incomplete due to the unavailable work stoppage data prior to collection. The availabilities currently in progress are also determined to be incomplete because the outcomes, in regard to schedule duration and future work stoppage submittals, are unknown. Even though the current availabilities have estimated completion dates, unanticipated delays and future work stoppages may affect the end date, and therefore these availabilities are excluded from the analysis. Even though this criterion limits the availability's statistical population to a small sample size, it is the purpose of the criterion to only analyze complete and known availability data sets. The six availabilities for the work stoppage analysis are displayed in Table 23 and are considered the historical data for which trends and commonalities are investigated.

Shipyard	Availability Type	Hull Type	Hull Name	Planned Length (Days)	Days Late (+) / Early (-)
NNSY	PIA	CVN	EISENHOWER	182	58
PSNSY	SRA	CVN	G WASHINGTON	119	26
PHNSY	DSRA	SSN	COLUMBUS	177	19
PSNSY	MMP	SSGN	MICHIGAN	106	14
PSNSY	PIA	CVN	JOHN C. STENNIS	184	1
NNSY	CM	SSN	NORFOLK	148	-5

Table 24. Work Stoppage Analysis Availability Summary

2. Data Organization

The work stoppage data in its provided form contains individual entries of active work stoppages based on the query date. The current form is able to provide insight on the quantity of active work stoppages per query; however it does not adequately provide insight on entire work stoppage durations and job delays. Instead of manually sorting and compiling the original seventy thousand lines of work stoppage data, a Microsoft Excel macro, a customizable series of commands, is capable of efficiently sorting and compiling the data into the user's requested form. The data from the six availabilities is separated into six individual data files before the macro is run.

The Microsoft Excel macro is composed of an "if-then" statement that extracts the job identification number, work stoppage reason, and date from individual work stoppage entries. A comparison between two entries is performed to determine if the job identification number and work stoppage reason are the same, and if the entries are one week apart. One week is considered six, seven, or eight days to account for fluctuations in time between queries, due to days off for federal holidays. For this research, it is assumed that if a job is present on multiple consecutive weeks and it has the same work stoppage reason throughout, then that is considered a single work stoppage with the duration in weeks equal to the number of consecutive entries. If all three criterion are not met, the work stoppage entry is considered a single duration. Using Table 21 as an example, the macro will result in the sample output in Table 24. Job ending in "S08" experienced an interference/coordination (IC) work stoppage at two different times in the availability, one in December and again in June, accounting for two separate outputs in Table 24.

JO-KO/SA#	Work Stoppage Reason	Duration (weeks)
3621Q02802-A01	TD	2
36SRB83101-R11	MAT	1
3635N84005-S08	IC	1
3635N84005-S08	IC	1

Table 25. Sample Macro Output

In order to quantify work stoppage durations, the length estimation discussed earlier is utilized. As stated, each work stoppage entry is estimated to have a duration range between one day and 13 days, with an average of seven days, or one week. This average of one week is taken as an assumption in which to classify a work stoppage entry. Similarly, a work stoppage with two or three consecutive entries is delayed two or three weeks, respectively. This assumption may not be precise in terms of actual duration, however it can provide general information on trends and commonalities.

The analysis further assumes that all jobs within the availability are executed according to the planned duration. Availability planning data, which includes the planned (estimated) job durations and the network diagram of sequential and concurrent jobs, is not available for analysis and therefore the planning durations must be assumed to be accurate. In part, it is further assumed that if a job is delayed and will not meet the planned completion date, a work stoppage has been submitted to document the delay.

C. WORK STOPPAGES BY LENGTH

Each of the six availabilities is split into two data sets. The first data set includes all the work stoppage data, regardless of the color-coded criticality. These data allow for the identification of any significant factors causing availability lateness as it relates to the overall execution of the availability. The second data set includes only the work stoppages on or near the critical path, identified as "red" in the entry's color code. The EPR suggests failure to act on a "red" labeled work stoppage will likely result in missing an important milestone or key event. As a result, the identified critical work stoppages are analyzed separately.

Each data set is organized based on work stoppage reason and by duration. This organization allows the mean duration length, standard deviation, and standard error of the mean to be determined for each work stoppage reason. Appendix C contains statistical summaries of the data sets of the six availabilities.

1. Complete Work Stoppage Data

The mean lengths of work stoppages for each reason are displayed in Table 25. Standard errors of the means are displayed in Appendix C. The six availabilities are sorted in descending order of lateness with the expectation of observing higher mean work stoppage lengths associated with the later availabilities. Unfortunately, no apparent simple association between mean length per work stoppage reason and availability lateness can be made.

Mean Length of Work Stoppage Duration (weeks)	Work Stoppage Reason: MAT	IC	TD	TL	SAF	W	WC	RSC	Total WS
EISENHOWER PIA (58 Days Late)	2.06	2.12	1.84	1.00	1.53	2.00	2.35	1.84	1.99
WASHINGTON SRA (26 Days Late)	1.83	1.24	1.50	2.50	1.00	2.20	1.57	1.33	1.65
COLUMBUS DSRA (19 Days Late)	1.40	1.86	1.41	1.39	0.00	1.50	1.77	1.29	1.56
MICHIGAN MMP (14 Days Late)	1.61	1.70	1.60	2.00	2.00	0.00	1.50	1.60	1.66
STENNIS PIA (1 Days Late)	1.88	2.18	1.76	1.36	2.00	3.00	2.20	1.67	1.97
NORFOLK CM (5 Days Early)	1.09	1.34	1.24	0.00	0.00	1.50	1.50	1.00	1.26

Table 26. Work Stoppage Reason Mean Length Summary

Due the high variety and limited replications of hull and availability types in the sample, the influence of these factors as it relates to average work stoppage length cannot be determined. In order to provide some insight, a comparison is conducted between the EISENHOWER PIA and the STENNIS PIA, similar hull and availability type, using a student t-test with the null hypothesis stating the difference between the mean lengths of all work stoppages is zero. Comparing the mean length of the availability's total work stoppages (Total WS in Table 25) results in the failure to reject the null hypothesis. This result may signify that lengths per work stoppage reason are not a factor in availability lateness, since the compared availabilities differ significantly on number of days late but do not differ based on mean length. Although it would be nice to rule out work stoppage lengths as a contributor to lateness, the method of work stoppage length estimation is surely an error contributor. The criticality of the work stoppages may also be a factor in explaining the failure in finding an association. This data is composed of work stoppages both on (red color-coded) and off (green and yellow color-coded) the critical chain and therefore the less critical work stoppages may be influencing the mean lengths of the work stoppage reasons. This hypothesis is further considered in the statistics analysis section of red color-coded work stoppages.

Although these data do not show availability lateness association, they do describe the dynamic of each availability with respect to work stoppages. By ranking each work stoppage reason's mean length relative to the other reasons within the same availability, it is concluded that resource work stoppages (RSC) are continually in the lower half of the rankings, signifying a shorter mean stoppage length. Conversely, interference/coordination work stoppages (IC) are in the top three, signifying some of the longest mean delays, five out six times.

Rankings	MAT	IC	TD	TL	SAF	W	WC	RSC
EISENHOWER PIA (58 Days Late)	3	2	6	8	7	4	1	5
WASHINGTON SRA (26 Days Late)	3	7	5	1	8	2	4	6
COLUMBUS DSRA (19 Days Late)	5	1	4	6	8	3	2	7
MICHIGAN MMP (14 Days Late)	4	3	5	1	1	8	7	5
STENNIS PIA (1 Days Late)	5	3	6	8	4	1	2	7
NORFOLK CM (5 Days Early)	5	3	4	7	7	1	1	6

Work Stoppage Reason

Table 27. Relative Work Stoppage Duration Rankings

2. Red Color-Coded Work Stoppage Data

Table 27 summarizes the average work stoppage lengths by reason for work stoppages identified as critical. Standard errors of the means are displayed in Appendix C. Similar to the complete work stoppage data analysis, there is no apparent simple association between availability lateness and average work stoppage length. The same student

t-test is performed, comparing total work stoppage mean length between the EISENHOWER and STENNIS PIAs, and again results in the failure to reject the null hypothesis that the work stoppage mean lengths are the same.

Mean Length of Work Stoppage Duration (weeks)	Work Stoppage Reason: MAT	IC	TD	TL	SAF	W	WC	RSC	Total WS
EISENHOWER PIA (58 Days Late)	1.34	1.55	1.34	1.00	1.00	1.00	1.37	1.29	1.40
WASHINGTON SRA (26 Days Late)	1.39	1.30	1.19	0.00	1.00	1.33	1.43	1.33	1.31
COLUMBUS DSRA (19 Days Late)	1.22	1.45	1.07	1.60	0.00	1.00	1.88	1.15	1.32
MICHIGAN MMP (14 Days Late)	1.47	1.55	1.23	2.00	1.00	0.00	1.00	1.00	1.48
STENNIS PIA (1 Days Late)	1.22	1.59	1.21	1.00	0.00	1.25	1.57	1.43	1.42
NORFOLK CM (5 Days Early)	1.00	1.30	1.14	0.00	0.00	1.33	1.00	1.00	1.19

Table 28. Red Color-Coded Work Stoppage Reason Mean Length Summary

The average length and the standard deviation (not shown but displayed in Appendix C) of the red-color coded data are smaller than the complete data set's average length and standard deviation. The smaller values represent a shorter mean delay and a tighter empirical distribution of lengths. As the highest prioritized jobs, the red coded work stoppages are better supported and the delays are quickly resolved to ensure continuous flow of the critical chain. This is attributed to the Daily Priority List (DPL) and the project team's continual focus on the list.

Ordering the reasons for work stoppages using mean lengths of the stoppages results in the rankings displayed in Table 28. Interference/coordination as well as work control (WC) stoppages are ranked in the top two positions, signifying longest mean length, in over half of the availabilities analyzed, and in the top 50% of the rankings five of six times. These are the largest groupings observed and are worth noting.

Rankings	MAT	IC	TD	TL	SAF	W	WC	RSC
	Work Stoppage Reason							
EISENHOWER PIA (58 Days Late)	3	1	4	6	6	6	2	5
WASHINGTON SRA (26 Days Late)	2	5	6	8	7	3	1	3
COLUMBUS DSRA (19 Days Late)	4	3	6	2	8	7	1	5
MICHIGAN MMP (14 Days Late)	3	2	4	1	5	8	5	5
STENNIS PIA (1 Days Late)	5	1	6	7	8	4	2	3
NORFOLK CM (5 Days Early)	4	2	3	7	7	1	4	4

Table 29. Relative Red-Color Coded Work Stoppage Duration Rankings

D. WORK STOPPAGES BY QUANTITY

Each of the eight reasons' total number of work stoppages is tallied and the percent of the availability's total work stoppages for each reason is calculated. Table 29 displays the percentages for red color-coded work stoppages. The tallied quantities for both complete and red color-coded data sets are displayed in Appendix D. Although no direct association is observed between percentage of work stoppages by reason and availability lateness, material (MAT), interference/coordination, and technical direction (TD) are consistently the three highest percentages for which red color-coded work stoppages are experienced. Similar percentages are observed in the complete work stoppage data set, with the same three work stoppage reasons having the highest percentages.

Percentage of Total Work Stoppages	MAT	IC	TD	TL	SAF	W	WC	RSC
	Work Stoppage Reason							
EISENHOWER PIA (58 Days Late)	27.6%	33.9%	24.6%	0.3%	1.4%	1.4%	5.5%	5.3%
WASHINGTON SRA (26 Days Late)	37.5%	11.4%	35.2%	0.0%	1.1%	3.4%	8.0%	3.4%
COLUMBUS DSRA (19 Days Late)	14.0%	38.6%	31.6%	2.2%	0.0%	0.4%	7.5%	5.7%
MICHIGAN MMP (14 Days Late)	34.4%	53.6%	6.8%	0.5%	1.0%	0.0%	1.6%	2.1%
STENNIS PIA (1 Days Late)	22.1%	49.1%	16.8%	0.9%	0.0%	1.8%	6.2%	3.1%
NORFOLK CM (5 Days Early)	20.3%	46.9%	21.9%	0.0%	0.0%	4.7%	3.1%	3.1%

Table 30. Percentage of Availability's Total Red Color-Coded Work Stoppages

E. WORK STOPPAGES BY TIME-IN-AVAILABILITY

As an availability progresses from the planning and preparation phase, to the execution phase, and finally to the testing phase, the management team's focus is always shifting. The framework of the planning phase is known as the left-to-right sweep. This sweep aims to ensure all lessons learned and best practices from past and ongoing availabilities are incorporated into the planning process (NAVSEA 07 2009). During this phase, the support work (to include prefabrication and manufacturing work) is the focus to ensure the infrastructure and support services are ready for the execution phase. The execution phase is where the majority of the production work, known in the shipyard industry as "wrench turning," takes place. The focus of the execution phase is to ensure the continuous forward movement of the work package jobs through the prioritization of jobs. The testing phase occurs at the end of the availability, with the focus of assessing the quality of the work performed.

The change in phases may be reflected in changes in reasons for work stoppages. The work stoppage data for the six availabilities is organized based on time-in-availability that the work stoppage occurred with the intent to observe the shifts in the focuses, as well as to identify any associations between work stoppages and availability lateness. Each availability is divided into three time segments: time before the start of the availability, the planned duration, and the time after the planned completion date of the availability. The planned availability duration is further segmented into tenths. SEA04X starts collecting work stoppage data eight weeks prior to availability start; support work normally starts during this eight week period. The planned availability duration (availability's planned completion date minus start date) is split into tenths to account for the difference in availability lengths and to allow for comparison on the same time scale. The work stoppages are organized by reason and by the time they are experienced during the availability. This time is determined based upon the availability's start date and the query date of the work stoppage entry. The complete and red color-coded data sets organized by time-in-availability are displayed in Appendix E.

Figure 22 displays the number of work stoppages by reason for the COLUMBUS (SSN 762) DSRA as a function of time of occurrence during its availability. The shift in the focus from the planning and preparation phase to the execution phase is observed in the changing numbers of work stoppages due to different reasons.

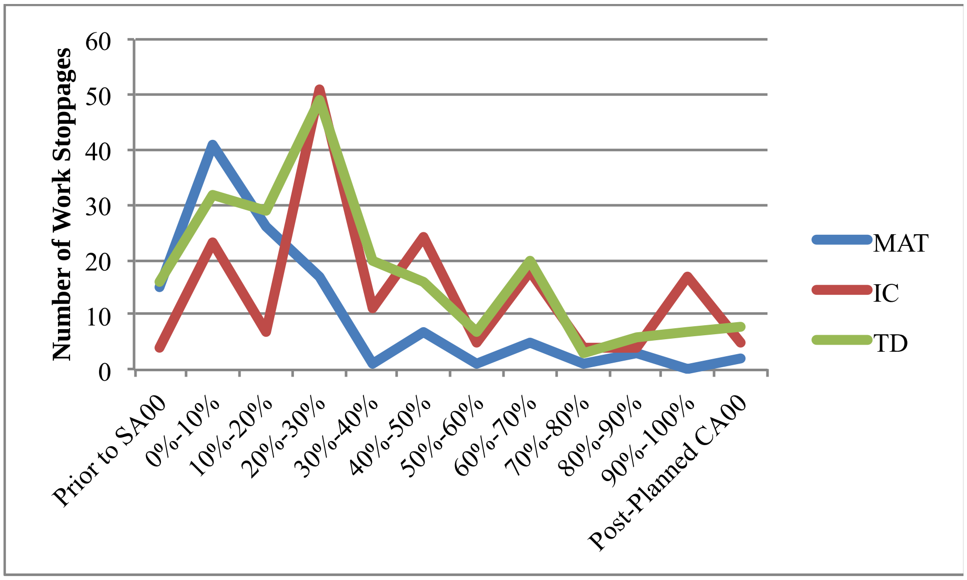

Figure 22. Quantity of MAT, IC, and TD Work Stoppages by Time-in-Availability

Prior to the start of the COLUMBUS DSRA, material and technical direction work stoppages are responsible for the largest numbers of delays. This can be attributed to the support and prefabrication work being performed before the production work commences. During the first 30% of the availability, there is a gradual decrease in material work stoppages and a rapid increase in interference/coordination stoppages. This is due to the focus shift from planning/preparation to execution, where production work is on the rise and the on-going jobs are interfering with one another. At this point in the availability, the management team must prioritize jobs and assign precedence in order to keep work moving. The shift in focus to execution is further amplified by the continual increase in technical direction work stoppages, with the bulk of these experienced during the first 30% of the availability.

The complete data set of the COLUMBUS DSRA provides the clearest example of observing this shift. Although the shift from planning to execution is not visually apparent in every availability, the number of interference/coordination work stoppages in all six of the analyzed availabilities tend to be small at the beginning and end of the availability and with the majority located in 30%–70% range of the availability. Graphical representations with respect to material, interference/coordination, and technical direction, for all historical availabilities are displayed in Appendix E.

1. Pre-availability Work Stoppage Ratio

Comparison of the number of work stoppages experienced prior to availability start and the number of work stoppages experienced during the execution phase in the complete data set suggests that availabilities that are close to completing on-time experience a relatively smaller number of work stoppages before the availability starts than during it. As a result of this suggestion, ratios are calculated by dividing the number of work stoppages experienced prior to the start of the availability by the total number of work stoppages experienced up until to the desired point in time during the availability. For example, to calculate this pre-availability work stoppage ratio for the first 50% of the availability, the number of work stoppages prior to availability start is divided by the sum of the total number of work stoppages experienced up until the 50% point, to include the work stoppages prior to the availability start. Table 30 shows this ratio (in percentage form) for all availabilities.

Point in Time of Availability	EISENHOWER PIA (58 Days Late)	WASHINGTON SRA (26 Days Late)	COLUMBUS DSRA (19 Days Late)	MICHIGAN MMP (14 Days Late)	STENNIS PIA (1 Days Late)	NORFOLK CM (5 Days Early)
10%	66.03%	60.66%	30.86%	93.80%	28.68%	0.00%
20%	50.14%	38.76%	22.33%	35.44%	12.49%	0.00%
30%	37.16%	20.22%	14.30%	28.47%	7.86%	0.00%
40%	28.15%	16.41%	12.95%	13.99%	5.22%	0.00%
50%	23.63%	12.98%	11.31%	9.78%	3.57%	0.00%
60%	20.14%	11.34%	11.00%	7.59%	2.73%	0.00%
70%	16.41%	11.30%	9.92%	6.54%	2.36%	0.00%
80%	15.10%	10.65%	9.75%	5.88%	2.26%	0.00%
90%	13.85%	10.49%	9.48%	5.82%	2.23%	0.00%
100%	13.56%	10.18%	9.04%	5.56%	2.22%	0.00%
Post-Planned CA00	12.91%	9.52%	8.79%	5.42%	2.22%	0.00%

Table 31. Complete Data Set Pre-Availability Work Stoppage Ratio

Beginning at the 50% point in the availability and onward, a trend is observed with the higher percentages of pre-availability work stoppages associated with the later finishing availabilities. Figure 23 is an example of the pre-availability ratio for the 50%

point of the availability length versus their respective number of days late. Similar trend lines are observed at the 60%, 70%, 80%, 90%, 100%, and the post-planned completion date.

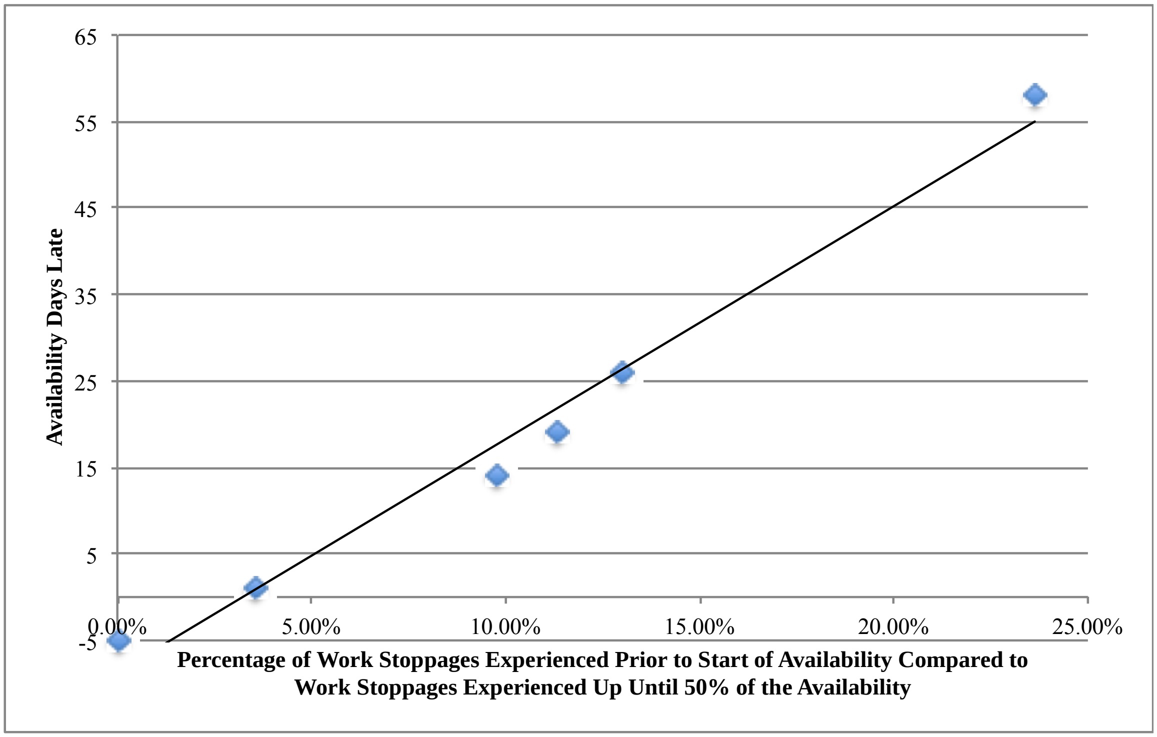

Figure 23. Pre-Availability Work Stoppage Ratio at 50% Point of Planned Availability

The approximate linear relationship displayed in Figure 23 provides the first indication of a positive association between numbers of work stoppages and availability lateness. The association is attributed to the number of work stoppages experienced during the planning/preparation phase as compared to the execution phase of the availability; the more work stoppages that are experienced during the planning/preparation phase, the more likely the availability will not be completed on time. This association, while it may provide information on availability lateness, must be understood with two caveats. The first is of course the limited amount of provided data. A similar comparison with a data set containing the true number of work stoppages is recommended for association validation. Secondly, SEA 04X did maintain consistency by starting data collection eight weeks prior to the availability start; however, without any additional information on the length of the planning phases, it can only be assumed that all planning phases and availability preparations were conducted during similar lengths of time.

It can further be assumed without any additional information on the planning and execution phases of these historical availabilities, that delays experienced prior to the start of an availability, during the planning phase, affect the ability of the execution phase to be carried out as planned. This seems plausible since the majority of the work accomplished prior to the start of the availability is in preparation for the future production work. If these supporting jobs are not ready at the start of the availability, jobs in the execution phase will be missing the supportive infrastructure required for completion.

F. SUMMARY

The analysis of the work stoppage data provides observations of general trends for the six historical availabilities. In addition, by comparing the number of work stoppages experienced prior to the start of the availability to the number experienced during the availability, it is found that more work stoppages during the planning/preparation stage of an availability is associated with a higher likelihood that the availability will not be completed on time. An in-depth study using a larger sample of availabilities is recommended to verify this observation.

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VI. CONCLUSION AND FUTURE STUDIES

A. SUMMARY OF STUDIES

Shipyard performance data are summarized and displayed in various ways to gain insight into possible reasons behind availability lateness. Studies that have been conducted are:

- Comparison of the percentage of availabilities that are late at the four different shipyards to determine possible differences between shipyards.
- Comparison of the percentage of submarine availabilities that are late and the percentage of carrier availabilities that are late across all four shipyards to investigate if the different platforms types have similar likelihoods of finishing late.
- Cost performances of late and on-schedule availabilities are compared.
- Comparison between availabilities of different lengths with regard to the number of days late as a percentage of scheduled length.
- Investigation of possible association between the days late percentage of availabilities and the number of simultaneous availabilities underway in the shipyard; and changes in the days late percentage across different time periods from 2003 to 2011.
- Availability lateness in Puget Sound and Portsmouth is studied for projects with various durations during inclement weather months to investigate possible seasonal impacts.
- The days late percentage of submarine availability in Puget Sound is studied for possible associations between the number of simultaneous carrier availabilities underway and submarine availability lateness.
- The number of planned and spent man-days per month are compared for late and on-schedule availabilities.

This study is limited to data on 108 completed availabilities. The smallness of the sample size and apparent improvement in availability lateness over time limit the ability to state “statistically significant” conclusions. However, the results are suggestive and suggest areas for further investigation.

The work stoppage analysis investigates the interactions and effects of delays during an execution of an availability. Although the provided work stoppage data is only a weekly snapshot of the number, reason, and duration of work stoppages submitted, trends with respect to availability lateness and commonalities between all types of availabilities are discovered. The collection of work stoppage data is composed weekly of work stoppage entries between 24 May 2010 and 05 Dec 2011. Each entry is compared to one another in order to group similar entries in terms of job number and work stoppage reason. This organization method is the foundation for the work stoppage research and allows for the analysis to examine work stoppages in terms of the work stoppage lengths, quantities, and time-in-availability.

B. ADDRESSING THE CONCERNS OF THE SUBJECT MATTER EXPERTS

The following analyses are conducted to study possible associations between lack of skilled personnel and availability lateness: a comparison of estimated number of man-days spent per month expended during the availability and the estimated planned number of man-days per month, utilizing values given of AQWP and BQWP respectively for each completed availability; and a comparison of CP values for late and timely availabilities.

CP ratios can be an indication of the skill level of those getting the work done. If the actual amount of work charged to complete the availability, AQWP, is less than the planned amount of work to complete the availability, BQWP, this may be indicative of a skilled labor force completing work in a timelier fashion than the initially set standard. If AQWP is greater than BQWP, then it is possible that the workforce is not as skilled as initially thought and the work to be performed takes longer than initially expected, affecting availability lateness. If personnel resources are not available for certain time periods during availabilities, perhaps due to other availabilities temporarily drawing from the resource pool, then the AQWP per month should be less than the BQWP per month if certain work cannot be accomplished due to the personnel absence. The comparison of AQWP per month and BQWP per month shows the general differences between late and timely availabilities possibly resulting from differing commitments of skilled personnel resources to the project. Results show that late availabilities tend to charge less for work per month than is initially planned, whereas timely availabilities tend to charge more for work per month than is initially planned. This can be an indication that late availabilities are not committing the resources required.

Data pertaining specifically to new work added to an availability was not collected and an analysis of such data is not included in this study. However, comparisons of the BQWP per month for late availabilities and the BQWP per month for timely availabilities can possibly reflect an impact of new work since the results show that late availabilities have a higher mean BQWP per month than timely availabilities, reflecting a greater number of man-days required to complete the project work.

An initial hypothesis is that late availabilities tend to require more overtime work because the lack of adherence to the day to day schedule starting from the beginning of a project will result in an overload of work towards the end. A comparison is made of the mean overtime percentages of late availabilities and on-schedule availabilities to see if they are statistically significantly different. Results show that there is no statistically significant difference.

C. CONCLUSIONS AND RECOMMENDATIONS

The intention of this study is to find differences between late and timely availabilities, and to display availability data in different ways in order to discover unseen associations between certain factors and availability lateness. The research questions addressed are:

- Can a statistical analysis of the planned versus actual quantity of work performed provide information on availability lateness?
- Are there one or more public shipyards that are statistically different than the rest in terms of availability planning and execution performance?
- Does the quantity and/or length of work stoppages affect the execution phase of an availability?
- Can an analysis of historical work stoppage data identify possible predictors for schedule lateness?

Since this study covers a small number of availabilities completed in recent years, most statistical analyses lacked a sufficient number of data samples needed make "statistically significant" conclusions. However, the following list summarizes the findings of this study and provides areas for further investigation that can aid in the effort to reduce either the number of late availabilities or the availability's days late percentage.

1. Carrier Availabilities Finish On-Time More Often Than Submarine Availabilities

Puget Sound Naval Shipyard and Norfolk Naval Shipyard completed more availabilities on time than Pearl Harbor and Portsmouth, but there is no statistically significant difference in the percentages of late availabilities between any of the yards based on the number of availabilities studied. However, there is a statistically significant difference in the percentages of late carrier availabilities and late submarine availabilities, providing evidence that carrier availabilities have a greater probability of finishing on time than submarine availabilities.

2. On Time Availabilities Result in a Higher Cost Performance Ratio

Comparison of the CP ratios of late and on-schedule availabilities, suggest that late availabilities have a mean CP ratio of 0.87 and on-schedule availabilities have a mean CP ratio of 0.95. Less than 25 percent of late availabilities have a CP ratio of 0.95 or higher. It is reasonable to expect timely availabilities to have a CP ratio close to unity. However, it is important that the budgeted quantity of work performed accurately reflects the required number of man-days to complete the work in the availability. An area of future investigation can involve the analysis of work items often found in availability work packages to investigate if the amount of work charged for those work items equals the budgeted amount of man-days allocated for that work.

3. Shorter Availabilities Have a Larger Days Late Percentage

The days late percentage of an availability is defined as the number of days it is late as a percentage of the planned availability length. The days late percentage is significantly higher for short availabilities with planned lengths of 200 days or fewer. Short availabilities that are late have a mean days late percentage of 42 percent, whereas late availabilities longer than 200 days have mean days late percentages of 14 to 16 percent. Results also show that the mean number of days late for short availabilities is not statistically significantly different from the mean number of days late for medium length availabilities ranging from 200 to 400 days in length. This means that short and medium length availabilities often have comparable number of days late, even though short availabilities have a mean length of 131 days and medium length availabilities have a mean length of 332 days. An area for further investigation should involve an analysis of short availabilities to determine means to improve their planning process in order to reduce the mean number of days late and with it the days late percentage.

4. No Association Between the Number of Availabilities Underway in a Shipyard and Availability Lateness

The mean days late percentage is calculated for availabilities in years 2005 through 2009 at each shipyard. During these years, the number of simultaneous availabilities in a shipyard ranges from three to nine. The results suggest that more availabilities underway in a shipyard does not result in a larger days late percentage for those availabilities.

5. Decreasing Days Late Percentage at Pearl Harbor Naval Shipyard

The mean days late percentage of availabilities underway in Pearl Harbor Naval Shipyard in the 2003 to 2005 time period is roughly 79%, roughly 16% in the 2006 to 2008 time period, and roughly 10% in the 2009 to 2011 period. The days late percentage of the availabilities at Puget Sound and Portsmouth naval shipyards also show a downward trend after 2006. The mean days late percentage of the availabilities underway at Norfolk Naval Shipyard is consistent between 2003 and 2011 at around ten percent. An area of future investigation can be to find the reasons behind the significant decrease in the days late percentage at Pearl Harbor Naval Shipyard from 2003 to 2011.

6. No Association Between Submarine Availability Days Late Percentage and Concurrent Underway Carrier Availabilities

An analysis is conducted to compare the days late percentage of every completed submarine availability at Puget Sound Naval Shipyard with a calculated carrier impact factor. A carrier impact factor gives a means of weighting the number and duration of carrier availabilities that occurred at Puget Sound during the submarine's availability.

The larger the carrier impact factor, the larger the number and/or durations of simultaneous carrier availabilities. The initial hypothesis is that submarines that possessed a higher carrier impact factor have higher days late percentage, based on the assumption that carrier availabilities take priority over submarine availabilities and draw from the resource pool. The results show no association between the days late percentage and the carrier impact factor.

7. Late Availabilities Charge Less in Man-Days per Month Than the Planned Earned Value of Work per Month

Two estimates are calculated for this study: the actual quantity of work performed for an availability, divided by the actual monthly length of that availability, and the budgeted quantity of work performed for the availability, divided by the planned length in months of that availability. The means of these two estimates are compared separately for completed availabilities that finished late and availabilities that finished on time. Results show that the mean AQWP per month is less than the mean BQWP per month for late availabilities and greater for timely availabilities. This is possibly an indication that not as many personnel resources, whether a limited quantity or novice in skill level, are committed to late availabilities as the work requires and that more personnel resources, an abundance in quantity or veteran in skill level, are committed to timely availabilities than the plan states. Results also show that the mean BQWP per month for late availabilities is greater than the mean BQWP per month for timely availabilities by an amount of 1,192 man-days per month for submarine availabilities and 7,211 for carrier availabilities. Since the BQWP is a dynamic figure through the execution phase of a project, a greater mean BQWP for late availabilities can be the result of a greater magnitude of new and unexpected work added to those availabilities than that of timely availabilities. An area for further investigation can include an analysis of the transfer of personnel resources between availabilities across all shipyards and over specific time periods to examine the impacts on availability AQWP figures. Another area for further investigation involves the analysis of new work profiles of individual availabilities to determine the impact on BQWP figures.

8. No Association between Quantity or Length of Work Stoppage and Availability Lateness

The conjecture at the beginning of this analysis is that larger work stoppage lengths and larger numbers of work stoppage would be associated with the late running availabilities. Unfortunately, neither the mean length per work stoppage reason nor the total number of work stoppages appear associated with availability lateness. The small sample size of 6 availabilities may contribute to this finding. A better understanding of the work stoppages' effect on availability lateness can be accomplished if all work stoppage data is recorded; that is, all submitted work stoppages are recorded, accompanied by the true durations, and the availability's WebAIM schedule is provided. This information, when analyzed simultaneously, will allow for the work stoppage's impact on the schedule's float to be better quantified.

Although the number and mean length of work stoppages is not associated with availability lateness, the analysis did show material, interference/coordination, and technical direction are the most likely reasons for work stoppage. From an availability manager's perspective with the goal of minimizing delays, this analysis offers the following recommendation: ensure that material lead times are proactively managed and the planning of work item integration and scheduling is highly detailed and thorough.

9. On-Time Availabilities Have Relatively Smaller Numbers of Work Stoppages Prior to Availability Start

A display of the number of work stoppages occurring by time-in-availability suggests that on-time availabilities tend to experience smaller numbers of work stoppages prior to the start of the availability. Correspondingly, the late finishing availabilities tend to experience higher numbers of work stoppages prior to and during the early stages of the availability. Furthermore, organizing work stoppages by occurrence time-in-availability results in an approximate linear association between availability days late and the ratio of work stoppages experienced prior to the availability start to the total number of work stoppages experienced during the entire availability. This ratio, in percentage form, is larger for the later availabilities, signifying a higher number of work stoppages prior to availability start than during it, compared to the on-time availabilities. This finding is based on data from six completed availabilities and should be further examined using data from additional availabilities. However, even with the limited data, this association introduces the question as to why work stoppages experienced prior to the start of the availability affect the outcome of the availability. Without any additional knowledge as to the planning and execution phases of the analyzed availabilities, it is presumed that the work stoppages prior to the availability start are associated with the support and prefabrication work that takes place in preparation for the availability's execution. As a result of the delay in the preparation work, the production work planned during the execution phase may not have the required support services in place to execute on time.

APPENDIX A: TOP LEVEL SHIPYARD DATA

A. SHIPYARD AVAILABILITY COMPLETION DATA

Days Late	*Frequency*
<-10	1
-9 to 0	14
1 to 10	3
11 to 20	1
21 to 30	1
31 to 40	5
41 to 50	2
51 to 60	2
61 to 70	0
71 to 80	0
81 to 90	2
91 to 100	1
More	2

Table 32. Norfolk Naval Shipyard Availability Completion Based on Days Late

Days Late	*Frequency*
< -10	1
-9 to 0	3
1 to 10	2
11 to 20	2
21 to 30	3
31 to 40	0
41 to 50	1
51 to 60	2
61 to 70	0
71 to 80	2
81 to 90	2
91 to 100	0
More	5

Table 33. Pearl Harbor Naval Shipyard Availability Completion Based on Days Late

Days Late	*Frequency*
< -10	3
-9 to 0	0
1 to 10	2
11 to 20	2
21 to 30	2
31 to 40	0
41 to 50	0
51 to 60	3
61 to 70	1
71 to 80	1
81 to 90	1
91 to 100	1
More	5

Table 34. Portsmouth Naval Shipyard Availability Completion Based on Days Late

Days Late	*Frequency*
< -10	0
-9 to 0	15
1 to 10	2
11 to 20	4
21 to 30	2
31 to 40	1
41 to 50	1
51 to 60	0
61 to 70	1
71 to 80	0
81 to 90	0
91 to 100	0
More	4

Table 35. Puget Sound Naval Shipyard Availability Completion Based on Days Late

B. SHIPYARD GANTT CHARTS

The Gantt charts are color-coded with the blue bars representing submarine availabilities, the red representing carrier availabilities, the green representing LHD availabilities, the purple representing MTS availabilities, and the yellow representing an AS availability.

ID	Task Name	Start	Finish	2005–2009 (Q1–Q4)
1	FLA	8/1/2003	3/31/2006	0%
2	TRU	8/20/2003	2/18/2004	
3	BBE	1/15/2004	2/1/2005	-3.53%
4	RST	2/3/2004	12/17/2004	
5	PRT	11/1/2004	12/30/2005	16.44%
6	HPN	1/5/2005	3/31/2006	11.08%
7	GRG	3/9/2005	12/21/2007	8.77%
8	NEW	4/25/2005	8/22/2005	41.67%
9	ENW	6/20/2005	10/20/2005	-0%
10	CHR	9/30/2005	9/21/2007	39.65%
11	TRN	1/9/2006	12/22/2006	9.12%
12	GWA	10/2/2006	8/30/2007	-0.89%
13	ALK	11/1/2006	3/5/2009	3.89%
14	RET	3/7/2007	12/5/2007	-0.36%
15	TSN	4/2/2007	10/24/2008	17.21%
16	BAT	9/5/2007	5/6/2008	-0.41%
17	ANT	10/1/2007	3/11/2008	35.83%
18	ENR	1/22/2008	7/23/2008	0.55%
19	WAP	3/19/2008	12/8/2008	7.76%
20	AGT	4/15/2008	4/14/2009	-0.27%
21	SAM	5/15/2008	12/22/2008	20.11%
22	TUA	8/18/2008	2/13/2009	-2.16%
23	NFK	10/6/2008	3/6/2009	28.57%
24	KRS	12/30/2008	11/18/2009	12.15%
25	TEN	1/23/2009	8/2/2011	12.32%
26	BEB	4/1/2009	8/31/2009	-0.65%
27	RSL	7/1/2009	9/1/2009	0%
28	WJM	8/12/2009	12/15/2009	5.04%
29	CAB	10/15/2009	1/29/2010	-0.93%
30	REA	11/18/2009	5/19/2010	0.55%
31	MTP	2/5/2010	7/27/2010	
32	SRB	4/16/2010	12/10/2010	
33	EHW	10/18/2010	6/15/2011	
34	8G1	1/10/2011	6/2/2011	

Figure 24. Availabilities at Norfolk Naval Shipyard from 2005 to 2009

ID	Project ID	Start	Finish
1	A22	10/29/2003	4/30/2004
2	A21	3/3/2004	10/15/2004
3	698	3/24/2004	3/9/2007
4	A71	6/2/2004	11/12/2004
5	B63	10/6/2004	12/17/2004
6	B18	1/11/2005	11/25/2005
7	A01	1/24/2005	6/23/2005
8	A72	6/14/2005	12/9/2005
9	B88	7/20/2005	7/17/2006
10	B73	1/3/2006	5/8/2006
11	C17	3/27/2006	4/1/2009
12	A52	5/18/2006	12/1/2006
13	A05	9/21/2006	12/15/2006
14	B71	4/9/2007	7/25/2008
15	708	9/27/2007	11/18/2008
16	B22	1/14/2008	6/16/2008
17	C73	5/5/2008	11/20/2009
18	713	8/18/2008	1/9/2009
19	C01	2/17/2009	2/8/2010
20	B15	3/16/2009	7/22/2009
21	B21	10/1/2009	11/10/2011
22	A98	11/9/2009	3/9/2010
23	762	1/1/2010	7/15/2010

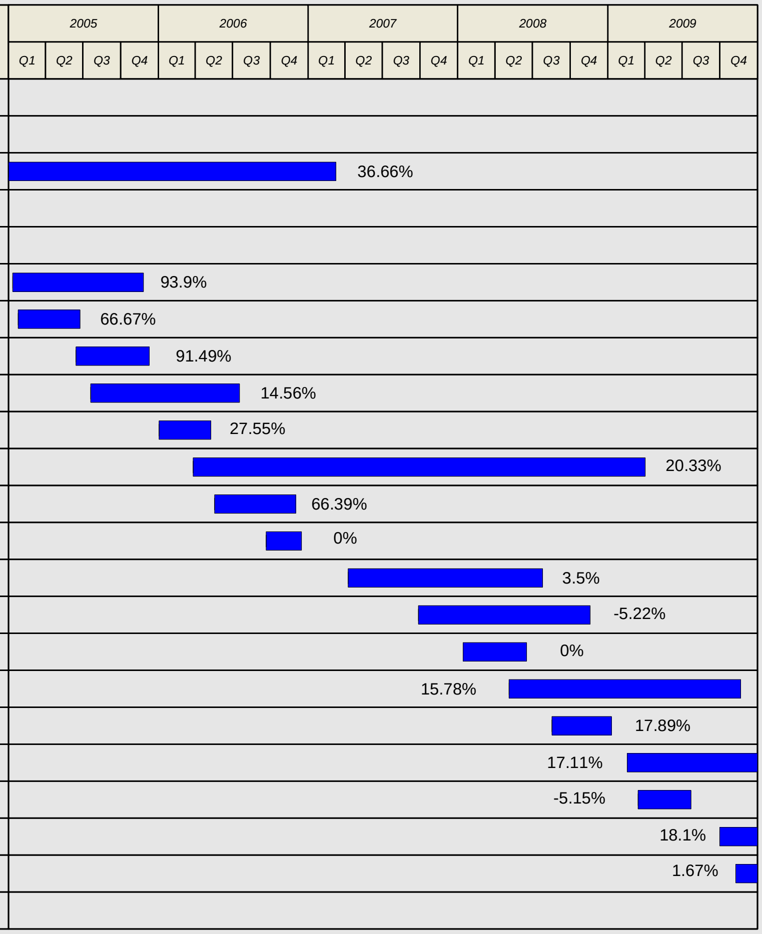

Figure 25. Availabilities at Pearl Harbor Naval Shipyard from 2005 to 2009

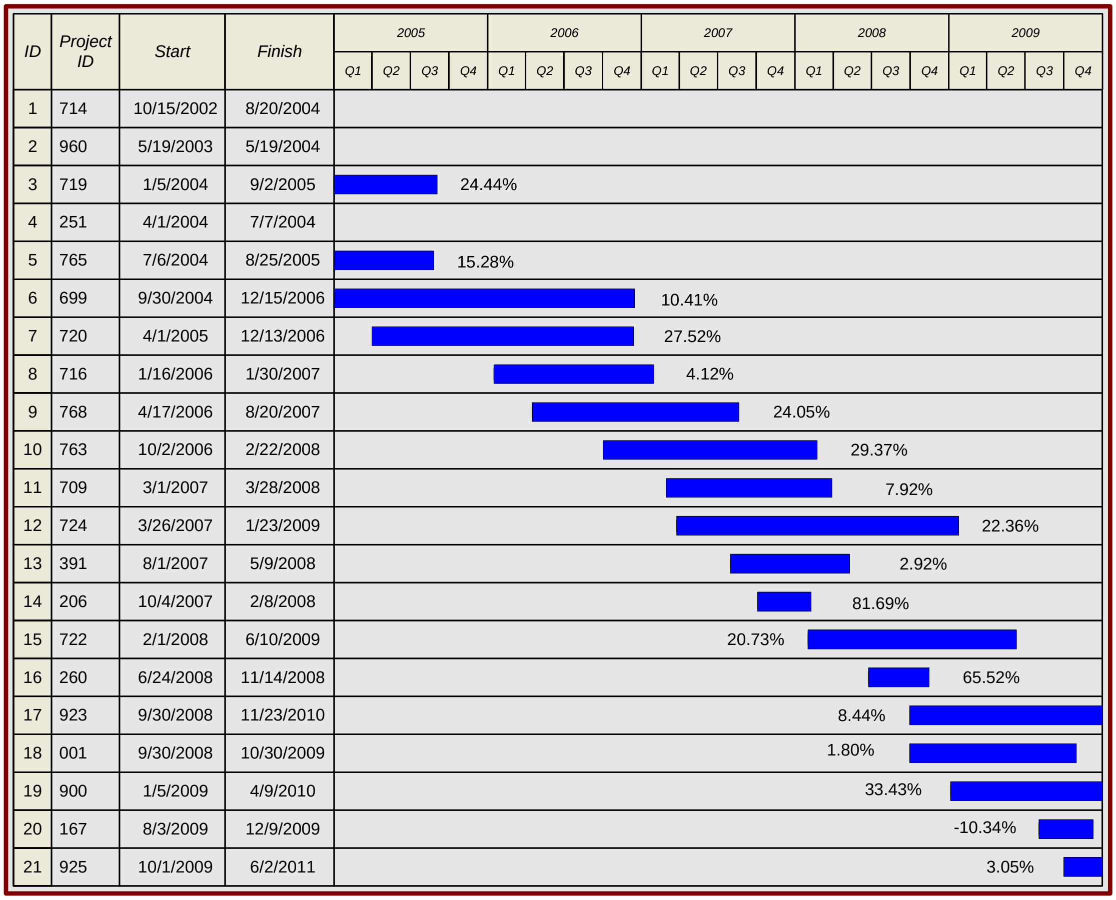

Figure 26. Availabilities at Portsmouth Naval Shipyard from 2005 to 2009

ID	Project ID	Start	Finish
1	N13	10/1/2001	7/8/2004
2	N26	11/15/2002	12/23/2005
3	S59	2/17/2003	7/30/2004
4	D72	6/23/2003	6/7/2004
5	A68	2/23/2004	8/23/2004
6	N27	3/15/2004	12/6/2006
7	N62	11/17/2004	12/15/2006
8	G74	1/17/2005	12/20/2005
9	S31	1/18/2006	5/16/2008
10	Q25	2/13/2006	5/26/2006
11	D68	3/1/2006	9/1/2006
12	Q54	8/1/2006	11/20/2006
13	G72	9/5/2006	6/29/2007
14	RB2	11/1/2006	11/28/2008
15	Q11	12/5/2006	4/14/2009
16	Q58	6/1/2007	9/11/2007
17	A76	5/1/2007	10/30/2007
18	74A	9/28/2007	3/27/2008
19	33Q	2/7/2008	5/7/2010
20	23A	3/5/2008	7/3/2008
21	68B	6/16/2008	12/16/2008
22	Q59	9/1/2008	12/19/2008
23	A73	1/5/2009	5/7/2009
24	72A	5/18/2009	1/15/2010
25	73B	1/11/2010	5/11/2010
26	23B	2/12/2010	12/23/2010
27	74B	6/14/2010	12/16/2010
28	73C	1/10/2011	6/3/2011
29	MNA	6/15/2011	10/13/2011

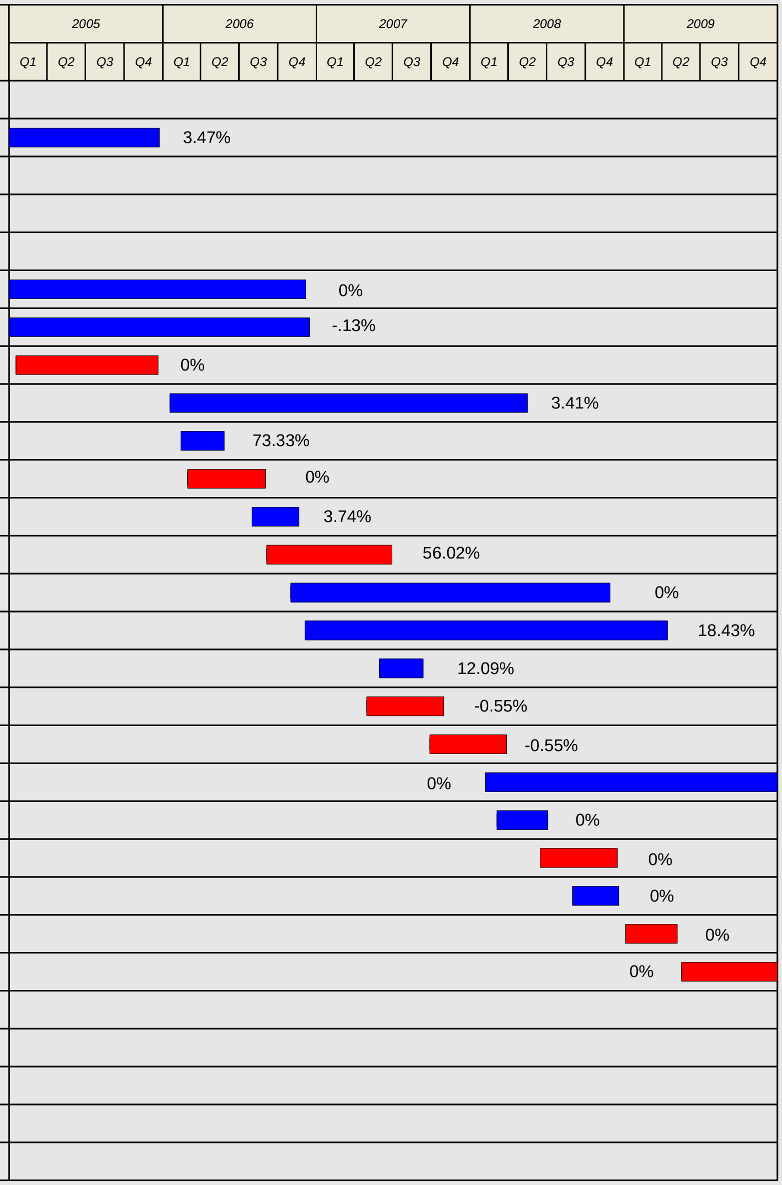

Figure 27. Availabilities at Puget Sound Naval Shipyard from 2005 to 2009

APPENDIX B: AQWP AND BQWP STATISTICAL COMPARISON RESULTS

Two-sample t-tests, assuming unequal variances, are conducted to compare the budgeted quantity of work planned (BQWP) per month (based on the planned duration) against the actual quantity of work planned (AQWP) per month (based in terms of both planned duration and actual duration).

A. AQWP AND BQWP PER MONTH FOR LATE AVAILABILITIES

Late Carriers	*BQWP/Month (planned)*	*AQWP/Month (actual)*
Mean	28675.38333	27588.05481
Variance	27602210.7	23688811.86
Observations	8	8
Hypothesized Mean Difference	0	
df	14	
t Stat	-0.429422794	
P(T<=t) one-tail	0.337075382	
t Critical one-tail	1.761310115	
P(T<=t) two-tail	0.674150765	
t Critical two-tail	2.144786681	

Late Submarines	*BQWP/Month (planned)*	*AQWP/Month (actual)*
Mean	11826.04595	11076.599
Variance	9037435.358	9475660.855
Observations	56	56
Hypothesized Mean Difference	0	
df	110	
t Stat	-1.303453007	
P(T<=t) one-tail	0.097570845	
t Critical one-tail	1.658824188	
P(T<=t) two-tail	0.19514169	
t Critical two-tail	1.981765221	

Table 36. T-test Results Comparing Means of AQWP/Month (Actual Duration) and BQWP/Month (Planned Duration) for Late Availabilities

Late Carriers	*BQWP/Month (planned)*	*AQWP/Month (planned)*
Mean	28675.38333	31702.51989
Variance	27602210.7	49647229.9
Observations	8	8
Hypothesized Mean Difference	0	
df	13	
t Stat	-0.974157853	
P(T<=t) one-tail	0.173878592	
t Critical one-tail	1.770933383	
P(T<=t) two-tail	0.347757183	
t Critical two-tail	2.160368652	

Late Submarines	*BQWP/Month (planned)*	*AQWP/Month (planned)*
Mean	11826.04595	14045.87422
Variance	9037435.358	16092768.44
Observations	56	56
Hypothesized Mean Difference	0	
df	102	
t Stat	-3.313716773	
P(T<=t) one-tail	0.000637503	
t Critical one-tail	1.659929976	
P(T<=t) two-tail	0.001275006	
t Critical two-tail	1.983495205	

Table 37. T-test Results Comparing Means of AQWP/Month (Planned Duration) and BQWP/Month (Planned Duration) for Late Availabilities

B. AQWP AND BQWP PER MONTH FOR TIMELY AVAILABILITIES

On-Time Carriers	*BQWP/Month (planned)*	*AQWP/Month (actual)*
Mean	21464.37741	21813.45841
Variance	46401735.52	52498999.07
Observations	16	16
Hypothesized Mean Difference	0	
df	30	
t Stat	-0.140406252	
P(T<=t) one-tail	0.444638755	
t Critical one-tail	1.697260851	
P(T<=t) two-tail	0.889277511	
t Critical two-tail	2.042272449	

On-Time Submarines	*BQWP/Month (planned)*	*AQWP/Month (actual)*
Mean	10634.38914	11778.56585
Variance	16285689.68	19246088.21
Observations	19	19
Hypothesized Mean Difference	0	
df	36	
t Stat	-0.836683947	
P(T<=t) one-tail	0.204145016	
t Critical one-tail	1.688297694	
P(T<=t) two-tail	0.408290032	
t Critical two-tail	2.028093987	

Table 38. T-test Results Comparing Means of AQWP/Month (Actual Duration) and BQWP/Month (Planned Duration) for Timely Availabilities

On-Time Carriers	*BQWP/Month (planned)*	*AQWP/Month (planned)*
Mean	21464.37741	21727.44338
Variance	46401735.52	51890943.57
Observations	16	16
Hypothesized Mean Difference	0	
df	30	
t Stat	-0.106136335	
P(T<=t) one-tail	0.458090364	
t Critical one-tail	1.697260851	
P(T<=t) two-tail	0.916180728	
t Critical two-tail	2.042272449	

On-Time Submarines	*BQWP/Month (planned)*	*AQWP/Month (planned)*
Mean	10634.38914	11493.5883
Variance	16285689.68	19202764.84
Observations	19	19
Hypothesized Mean Difference	0	
df	36	
t Stat	-0.628676321	
P(T<=t) one-tail	0.266764923	
t Critical one-tail	1.688297694	
P(T<=t) two-tail	0.533529847	
t Critical two-tail	2.028093987	

Table 39. T-test Results Comparing Means of AQWP/Month (Planned Duration) and BQWP/Month (Planned Duration) for Timely Availabilities

C. STANDARD ERRORS FOR MEAN AQWP AND BQWP PER MONTH

	Mean AQWP/Month (Actual Duration)	Standard Error	Mean BQWP/Month (Planned Duration)	Standard Error
Late Sub Avails	11076.6	411.4	11826.1	401.7
On-Time Sub Avails	11778.6	1006.5	10634.4	925.8
Late Carrier Avails	27588.1	1720.8	28675.4	1857.5
On-Time Carriers	21813.46	1811.4	21464.4	1703.0
Late Sub DSRA	9532.9	539.1	11645.7	679.2
On-Time Sub DSRA	10848.7	641.8	9981.5	526.9
Late Sub ERO	15490.3	1592.8	14579.7	1370.0
On-Time Sub ERO	15216.4	330.6	14309.1	650.4
Late Sub DMP	12913.1	457.4	13332.1	567.0
On-Time Sub DMP	13508	1278.8	11280.1	1091.7
Late Sub IA	4870.1	191.3	4859.2	225.1
On-Time Sub IA	5102.2	418	4571.2	318.6
Late Carrier PIA	27889.7	1838.9	29932.2	2806.8
On-Time Carrier PIA	23211.3	1552.1	23146.8	1585.3

	Mean AQWP/Month (Planned Duration)	Standard Error	Mean BQWP/Month (Planned Duration)	Standard Error
Late Sub Avails	14045.9	536.1	11826.1	401.7
On-Time Sub Avails	11493.6	1005.3	10634.4	925.8
Late Carrier Avails	31702.5	2491.2	28675.4	1857.5
On-Time Carriers	21727.4	1800.9	21464.4	1703.0

Table 40. Standard Errors for Mean AQWP per Month and Mean BQWP per Month in Man-Days

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APPENDIX C: WORK STOPPAGE DATA BY LENGTH

The tables are organized with the columns representing the eight reasons for work stoppage and the rows are the estimated number of work stoppages for each duration measured in weeks; the durations are in units of weeks. The table is populated with the number of work stoppages observed with respect to work stoppage reason and the number of consecutive entries (labeled as duration).

A. COMPLETE WORK STOPPAGE DATA SETS

		Work Stoppage Reason								
		MAT	IC	TD	TL	SAF	W	WC	RSC	Total WS
Duration (weeks)	1	379	423	479	16	61	33	55	94	1540
	2	142	186	150	0	1	9	22	36	546
	3	49	86	77	0	2	3	20	15	252
	4	36	53	35	0	1	4	6	8	143
	5	19	26	8	0	0	0	2	1	56
	6	21	14	14	0	3	3	1	3	59
	7	12	11	5	0	1	0	2	3	34
	8	2	4	5	0	0	0	1	0	12
	9	5	5	6	0	1	0	0	1	18
	10	3	3	0	0	0	0	1	0	7
	11	0	2	3	0	0	0	2	0	7
	12	0	1	0	0	0	1	0	0	2
	13	0	0	0	0	0	0	1	0	1
	14	0	1	0	0	0	0	0	0	1
	15	1	0	0	0	0	0	0	0	1
	16	1	1	0	0	0	0	0	0	2
	17	0	0	0	0	0	0	0	0	0
	18	0	0	0	0	0	0	0	0	0
	19	0	0	0	0	0	0	0	0	0
	20	0	0	0	0	0	0	0	0	0
	Total	670	816	782	16	70	53	113	161	2681
Mean Length of Stoppage (weeks)		2.06	2.12	1.84	1.00	1.53	2.00	2.35	1.84	1.99
Standard Deviation		1.83	1.79	1.52	0.00	1.57	1.94	2.21	1.40	1.73
Standard Error of Mean		0.07	0.06	0.05	0.00	0.19	0.27	0.21	0.11	0.03

Table 41. EISENHOWER (CVN 69) PIA

Work Stoppage Reason

Duration (weeks)	MAT	IC	TD	TL	SAF	W	WC	RSC	Total WS
1	71	17	86	1	1	5	9	4	194
2	23	3	19	0	0	3	3	2	53
3	11	1	8	0	0	0	1	0	21
4	6	0	5	1	0	0	1	0	13
5	5	0	1	0	0	1	0	0	7
6	2	0	0	0	0	1	0	0	3
7	1	0	1	0	0	0	0	0	2
8	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0
Total	119	21	120	2	1	10	14	6	293
Mean Length of Stoppage (weeks)	1.83	1.24	1.50	2.50	1.00	2.20	1.57	1.33	1.65
Standard Deviation	1.31	0.53	0.99	1.50	0.00	1.72	0.90	0.47	1.16
Standard Error of Mean	0.12	0.11	0.09	1.06	0.00	0.54	0.24	0.19	0.07

Table 42. GEORGE WASHINGTON (CVN 73) SRA

Work Stoppage Reason

Duration (weeks)	MAT	IC	TD	TL	SAF	W	WC	RSC	Total WS
1	81	94	156	12	0	1	21	19	384
2	31	41	36	5	0	1	4	3	121
3	5	21	16	1	0	0	2	2	47
4	1	9	2	0	0	0	2	0	14
5	1	6	1	0	0	0	0	0	8
6	0	0	2	0	0	0	0	0	2
7	0	0	0	0	0	0	0	0	0
8	0	1	0	0	0	0	0	0	1
9	0	1	0	0	0	0	0	0	1
10	0	0	0	0	0	0	1	0	1
11	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0
Total	119	173	213	18	0	2	30	24	579
Mean Length of Stoppage (weeks)	1.40	1.86	1.41	1.39	0.00	1.50	1.77	1.29	1.56
Standard Deviation	0.69	1.29	0.83	0.59	0.00	0.50	1.76	0.61	1.04
Standard Error of Mean	0.06	0.10	0.06	0.14	0.00	0.35	0.32	0.12	0.04

Table 43. COLUMBUS (SSN 762) DSRA

Duration (weeks)	MAT	IC	TD	TL	SAF	W	WC	RSC	Total WS
	Work Stoppage Reason								
1	66	89	18	0	1	0	4	4	182
2	21	37	6	1	0	0	1	0	66
3	7	10	6	0	1	0	1	0	25
4	2	9	0	0	0	0	0	1	12
5	4	2	0	0	0	0	0	0	6
6	1	0	0	0	0	0	0	0	1
7	0	1	0	0	0	0	0	0	1
8	0	1	0	0	0	0	0	0	1
9	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0
Total	101	149	30	1	2	0	6	5	294
Mean Length of Stoppage (weeks)	1.61	1.70	1.60	2.00	2.00	0.00	1.50	1.60	1.66
Standard Deviation	1.08	1.16	0.80	0.00	1.00	0.00	0.76	1.20	1.09
Standard Error of Mean	0.11	0.10	0.15	0.00	0.71	0.00	0.31	0.54	0.06

Table 44. MICHIGAN (SSGN 727) MMP

Duration (weeks)	MAT	IC	TD	TL	SAF	W	WC	RSC	Total WS
	Work Stoppage Reason								
1	166	257	187	12	4	4	24	81	735
2	94	128	70	1	0	8	13	38	352
3	46	66	25	0	0	1	1	10	149
4	16	32	15	0	0	0	1	5	69
5	5	22	3	1	0	0	0	1	32
6	4	14	5	0	1	0	1	2	27
7	1	7	3	0	0	0	1	1	13
8	1	2	1	0	0	0	1	0	5
9	1	2	1	0	0	1	1	0	6
10	0	4	0	0	0	0	1	0	5
11	0	0	0	0	0	0	0	0	0
12	0	1	0	0	0	0	0	0	1
13	0	0	0	0	0	1	0	0	1
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0
Total	334	535	310	14	5	15	44	138	1395
Mean Length of Stoppage (weeks)	1.88	2.18	1.76	1.36	2.00	3.00	2.20	1.67	1.97
Standard Deviation	1.21	1.71	1.30	1.04	2.00	3.27	2.22	1.08	1.52
Standard Error of Mean	0.07	0.07	0.07	0.28	0.89	0.84	0.33	0.09	0.04

Table 45. JOHN C STENNIS (CVN 74) PIA

Duration (weeks)	MAT	IC	TD	TL	SAF	W	WC	RSC	Total WS
1	29	40	23	0	0	5	1	2	100
2	3	5	0	0	0	0	1	0	9
3	0	3	1	0	0	0	0	0	4
4	0	2	0	0	0	1	0	0	3
5	0	0	1	0	0	0	0	0	1
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0
Total	32	50	25	0	0	6	2	2	117
Mean Length of Stoppage (weeks)	1.09	1.34	1.24	0.00	0.00	1.50	1.50	1.00	1.26
Standard Deviation	0.29	0.76	0.86	0.00	0.00	1.12	0.50	0.00	0.72
Standard Error of Mean	0.05	0.11	0.17	0.00	0.00	0.46	0.35	0.00	0.07

Work Stoppage Reason

Table 46. NORFOLK (SSN 714) CM

B. RED COLOR-CODED WORK STOPPAGE DATA SETS

Duration (weeks)	MAT	IC	TD	TL	SAF	W	WC	RSC	Total WS
	Work Stoppage Reason								
1	135	147	121	2	9	9	27	25	475
2	32	45	25	0	0	0	4	8	114
3	6	14	9	0	0	0	3	1	33
4	1	7	2	0	0	0	1	0	11
5	2	2	0	0	0	0	0	0	4
6	0	0	1	0	0	0	0	0	1
7	1	1	0	0	0	0	0	0	2
8	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
12	0	1	0	0	0	0	0	0	1
13	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0
Total	177	217	158	2	9	9	35	34	641
Mean Length of Stoppage (weeks)	1.34	1.55	1.34	1.00	1.00	1.00	1.37	1.29	1.40
Standard Deviation	0.80	1.15	0.74	0.00	0.00	0.00	0.76	0.52	0.90
Standard Error of Mean	0.06	0.08	0.06	0.00	0.00	0.00	0.13	0.09	0.04

Table 47. EISENHOWER (CVN 69) PIA

Duration (weeks)	MAT	IC	TD	TL	SAF	W	WC	RSC	Total WS
	Work Stoppage Reason								
1	24	8	25	0	1	2	5	2	67
2	6	1	6	0	0	1	1	1	16
3	2	1	0	0	0	0	1	0	4
4	1	0	0	0	0	0	0	0	1
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0
Total	33	10	31	0	1	3	7	3	88
Mean Length of Stoppage (weeks)	1.39	1.30	1.19	0.00	1.00	1.33	1.43	1.33	1.31
Standard Deviation	0.74	0.64	0.40	0.00	0.00	0.47	0.73	0.47	0.61
Standard Error of Mean	0.13	0.20	0.07	0.00	0.00	0.27	0.28	0.27	0.06

Table 48. GEORGE WASHINGTON (CVN 73) SRA

Work Stoppage Reason

Duration (weeks)	MAT	IC	TD	TL	SAF	W	WC	RSC	Total WS
1	26	63	68	3	0	1	8	12	181
2	5	16	3	1	0	0	5	0	30
3	1	5	1	1	0	0	2	1	11
4	0	2	0	0	0	0	2	0	4
5	0	2	0	0	0	0	0	0	2
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0
Total	32	88	72	5	0	1	17	13	228
Mean Length of Stoppage (weeks)	1.22	1.45	1.07	1.60	0.00	1.00	1.88	1.15	1.32
Standard Deviation	0.48	0.88	0.30	0.80	0.00	0.00	1.02	0.53	0.72
Standard Error of Mean	0.09	0.09	0.04	0.36	0.00	0.00	0.25	0.15	0.05

Table 49. COLUMBUS (SSN 762) DSRA

Work Stoppage Reason

Duration (weeks)	MAT	IC	TD	TL	SAF	W	WC	RSC	Total WS
1	48	70	11	0	2	0	3	4	138
2	13	22	1	1	0	0	0	0	37
3	1	4	1	0	0	0	0	0	6
4	1	5	0	0	0	0	0	0	6
5	2	0	0	0	0	0	0	0	2
6	1	0	0	0	0	0	0	0	1
7	0	2	0	0	0	0	0	0	2
8	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0
Total	66	103	13	1	2	0	3	4	192
Mean Length of Stoppage (weeks)	1.47	1.55	1.23	2.00	1.00	0.00	1.00	1.00	1.48
Standard Deviation	1.02	1.09	0.58	0.00	0.00	0.00	0.00	0.00	1.02
Standard Error of Mean	0.13	0.11	0.16	0.00	0.00	0.00	0.00	0.00	0.07

Table 50. MICHIGAN (SSGN 727) MMP

	Work Stoppage Reason								
Duration (weeks)	MAT	IC	TD	TL	SAF	W	WC	RSC	Total WS
1	40	76	33	2	0	3	11	4	169
2	9	18	4	0	0	1	1	3	36
3	1	11	0	0	0	0	0	0	12
4	0	3	0	0	0	0	1	0	4
5	0	2	1	0	0	0	1	0	4
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0
9	0	1	0	0	0	0	0	0	1
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0
Total	50	111	38	2	0	4	14	7	226
Mean Length of Stoppage (weeks)	1.22	1.59	1.21	1.00	0.00	1.25	1.57	1.43	1.42
Standard Deviation	0.46	1.15	0.69	0.00	0.00	0.43	1.24	0.49	0.96
Standard Error of Mean	0.07	0.11	0.11	0.00	0.00	0.22	0.33	0.19	0.06

Table 51. JOHN C STENNIS (CVN 74) PIA

	Work Stoppage Reason								
Duration (weeks)	MAT	IC	TD	TL	SAF	W	WC	RSC	Total WS
1	13	24	13	0	0	2	2	2	56
2	0	3	0	0	0	1	0	0	4
3	0	3	1	0	0	0	0	0	4
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0
Total	13	30	14	0	0	3	2	2	64
Mean Length of Stoppage (weeks)	1.00	1.30	1.14	0.00	0.00	1.33	1.00	1.00	1.19
Standard Deviation	0.00	0.64	0.52	0.00	0.00	0.47	0.00	0.00	0.53
Standard Error of Mean	0.00	0.12	0.14	0.00	0.00	0.27	0.00	0.00	0.07

Table 52. NORFOLK (SSN 714) CM

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APPENDIX D: WORK STOPPAGE DATA BY QUANTITY

The work stoppage entries are counted and sorted into the appropriate reason categories.

A. COMPLETE WORK STOPPAGE DATA SETS

Number of Work Stoppages	MAT	IC	TD	TL	SAF	W	WC	RSC	WS Total
EISENHOWER PIA (58 Days Late)	670	816	782	16	70	53	113	161	2681
WASHINGTON SRA (26 Days Late)	119	21	120	2	1	10	14	6	293
COLUMBUS DSRA (19 Days Late)	119	173	213	18	0	2	30	24	579
MICHIGAN MMP (14 Days Late)	101	149	30	1	2	0	6	5	294
STENNIS PIA (1 Days Late)	334	535	310	14	5	15	44	138	1395
NORFOLK CM (5 Days Early)	32	50	25	0	0	6	2	2	117

Work Stoppage Reason

Table 53. Quantity of Work Stoppages

B. RED COLOR-CODED WORK STOPPAGE DATA SETS

Number of Work Stoppages	MAT	IC	TD	TL	SAF	W	WC	RSC	WS Total
EISENHOWER PIA (58 Days Late)	177	217	158	2	9	9	35	34	641
WASHINGTON SRA (26 Days Late)	33	10	31	0	1	3	7	3	88
COLUMBUS DSRA (19 Days Late)	32	88	72	5	0	1	17	13	228
MICHIGAN MMP (14 Days Late)	66	103	13	1	2	0	3	4	192
STENNIS PIA (1 Days Late)	50	111	38	2	0	4	14	7	226
NORFOLK CM (5 Days Early)	13	30	14	0	0	3	2	2	64

Work Stoppage Reason

Table 54. Quantity of Red Color-Coded Work Stoppages

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APPENDIX E: WORK STOPPAGES BY TIME-IN-AVAILABILITY

The work stoppages are sorted based on reason and by time during the availability in which experienced. The figures corresponding to each table display the number of material (MAT), interference/coordination (IC), and technical direction (TD) work stoppages against the time-in-availability.

A. COMPLETE WORK STOPPAGE DATA SETS

Percentage of Planned Duration	Work Stoppage Reason								
	MAT	IC	TD	TL	SAF	W	WC	RSC	Total WS
Prior to SA00	123	21	197	0	0	0	4	1	346
0%-10%	30	73	56	1	2	2	2	12	178
10%-20%	45	29	77	1	1	0	8	5	166
20%-30%	61	79	72	2	0	5	3	19	241
30%-40%	50	62	83	1	52	1	15	34	298
40%-50%	41	84	70	0	2	2	7	29	235
50%-60%	36	121	50	8	0	10	10	19	254
60%-70%	104	139	90	2	0	7	24	25	391
70%-80%	52	78	31	0	3	1	7	10	182
80%-90%	62	81	40	0	1	4	14	5	207
90%-100%	15	18	4	1	1	9	4	1	53
Post-Planned CA00	51	31	12	0	8	12	15	1	130

Table 55. EISENHOWER (CVN 69) PIA

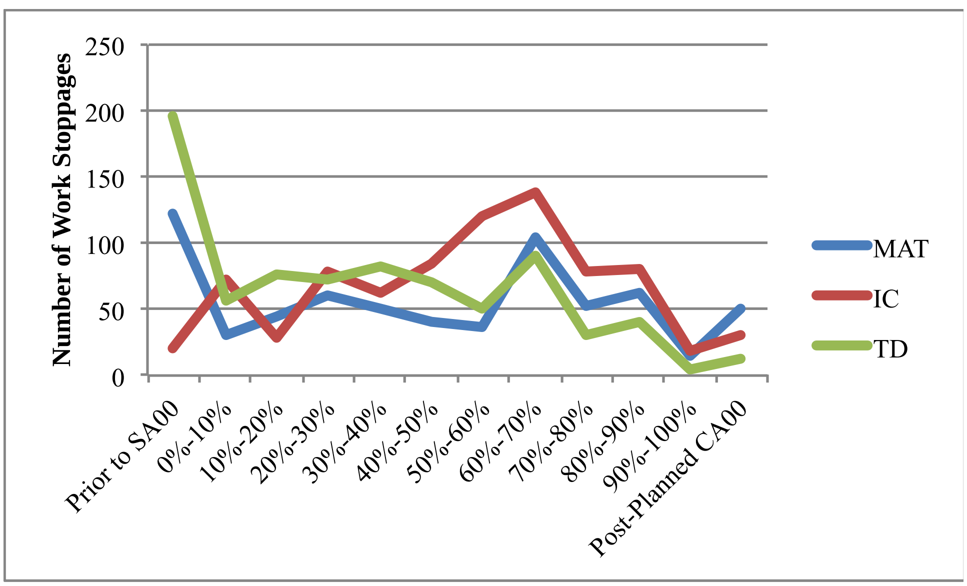

Figure 28. EISENHOWER (CVN 69) PIA

Percentage of Planned Duration	Work Stoppage Reason								
	MAT	IC	TD	TL	SAF	W	WC	RSC	Total
Prior to SA00	11	3	13	0	0	0	0	1	28
0%-10%	9	2	5	0	0	0	1	1	18
10%-20%	11	2	12	0	0	0	0	1	26
20%-30%	20	10	28	1	1	3	2	1	66
30%-40%	14	0	17	0	0	0	0	1	32
40%-50%	21	3	14	1	0	2	3	1	45
50%-60%	14	0	12	0	0	3	2	0	31
60%-70%	1	0	0	0	0	0	0	0	1
70%-80%	8	0	5	0	0	2	0	0	15
80%-90%	1	0	2	0	0	0	1	0	4
90%-100%	1	0	5	0	0	0	2	0	8
Post-Planned CA00	8	1	7	0	0	0	3	0	19

Table 56. GEORGE WASHINGTON (CVN 73) SRA

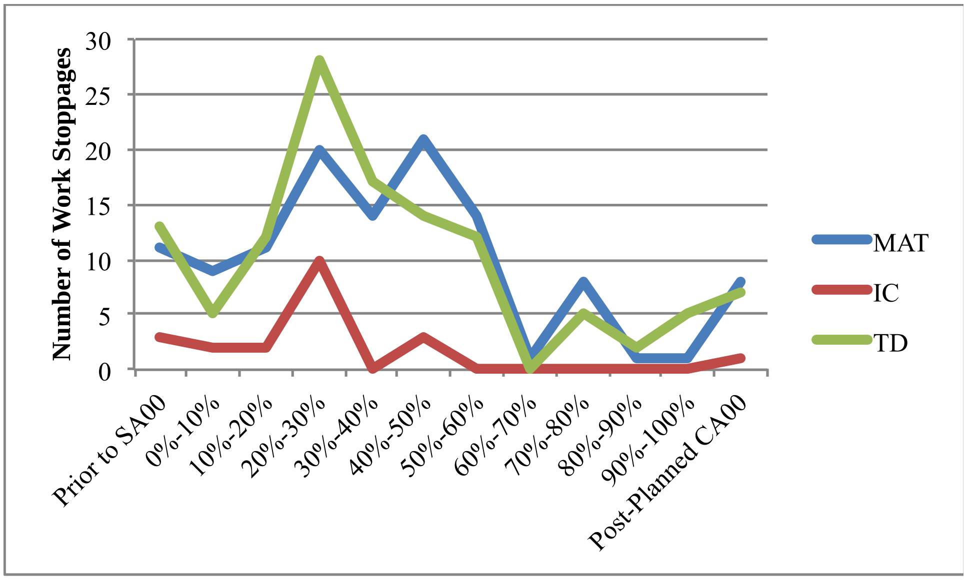

Figure 29. GEORGE WASHINGTON (CVN 73) SRA

Percentage of Planned Duration	Work Stoppage Reason								
	MAT	IC	TD	TL	SAF	W	WC	RSC	Total
Prior to SA00	15	4	16	3	0	0	11	2	51
0%-10%	41	23	32	7	0	1	6	4	114
10%-20%	26	7	29	1	0	0	0	0	63
20%-30%	17	51	49	3	0	1	4	3	128
30%-40%	1	11	20	1	0	0	0	4	37
40%-50%	7	24	16	3	0	0	4	3	57
50%-60%	1	5	7	0	0	0	0	0	13
60%-70%	5	18	20	0	0	0	2	5	50
70%-80%	1	4	3	0	0	0	0	1	9
80%-90%	3	4	6	0	0	0	2	0	15
90%-100%	0	17	7	0	0	0	1	1	26
Post-Planned CA00	2	5	8	0	0	0	0	1	16

Table 57. COLUMBUS (SSN 762) DSRA

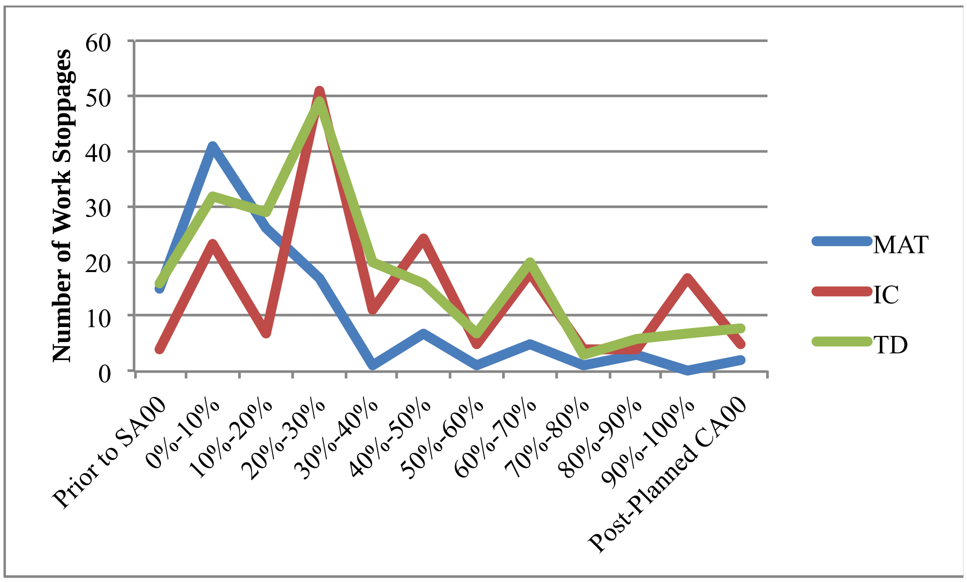

Figure 30. COLUMBUS (SSN 762) DSRA

Percentage of Planned Duration	MAT	IC	TD	TL	SAF	W	WC	RSC	Total
	Work Stoppage Reason								
Prior to SA00	10	2	4	0	0	0	0	0	16
0%-10%	1	0	0	0	0	0	0	0	1
10%-20%	15	7	3	0	0	0	2	1	28
20%-30%	1	6	4	0	0	0	0	0	11
30%-40%	12	34	8	0	1	0	2	1	58
40%-50%	21	20	5	1	0	0	1	1	49
50%-60%	16	26	3	0	0	0	0	2	47
60%-70%	7	24	1	0	1	0	1	0	34
70%-80%	15	10	2	0	0	0	0	0	27
80%-90%	1	2	0	0	0	0	0	0	3
90%-100%	1	12	0	0	0	0	0	0	13
Post-Planned CA00	1	6	0	0	0	0	0	0	7

Table 58. MICHIGAN (SSGN 727) MMP

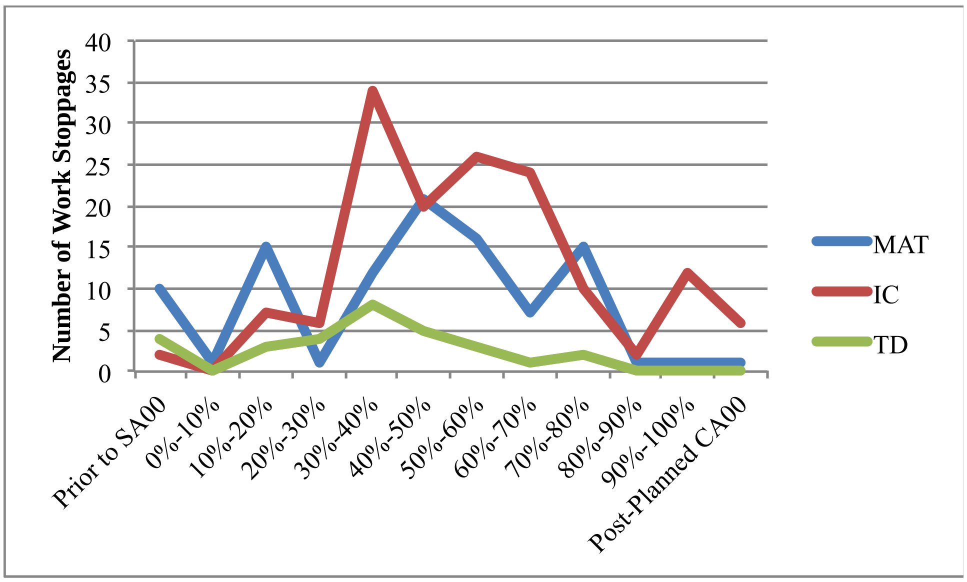

Figure 31. MICHIGAN (SSGN 727) MMP

Work Stoppage Reason

Percentage of Planned Duration	MAT	IC	TD	TL	SAF	W	WC	RSC	Total
Prior to SA00	4	0	12	0	0	1	7	7	31
0%-10%	13	19	27	0	0	0	10	8	77
10%-20%	32	48	40	2	1	0	1	16	140
20%-30%	21	62	38	1	1	2	1	20	146
30%-40%	47	62	54	4	2	1	3	26	199
40%-50%	61	126	51	2	1	5	9	19	274
50%-60%	57	108	61	2	0	6	5	30	269
60%-70%	52	89	21	3	0	0	4	10	179
70%-80%	38	10	2	0	0	0	2	2	54
80%-90%	7	10	4	0	0	0	1	0	22
90%-100%	1	1	0	0	0	0	1	0	3
Post-Planned CA00	1	0	0	0	0	0	0	0	1

Table 59. JOHN C STENNIS (CVN 74) PIA

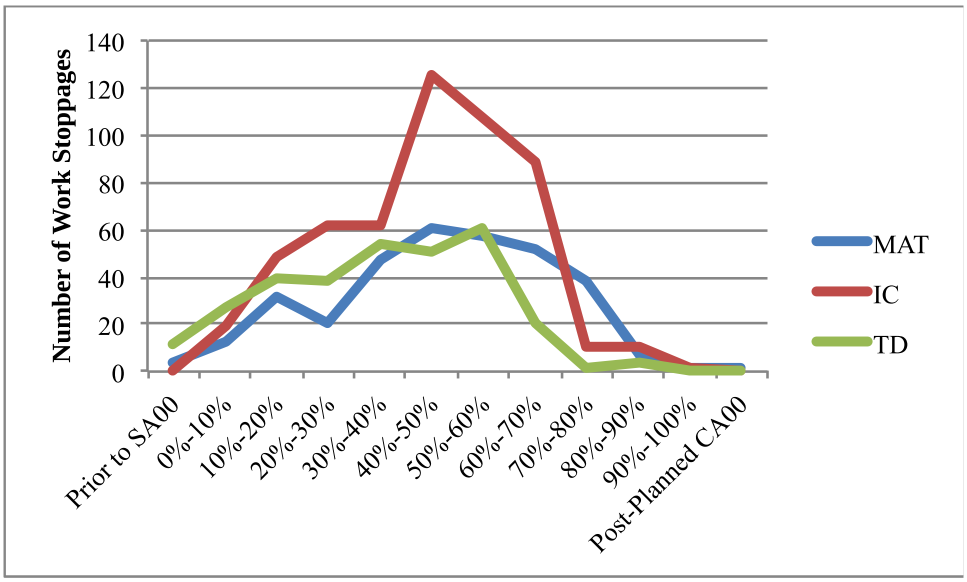

Figure 32. JOHN C STENNIS (CVN 74) PIA

Work Stoppage Reason

Percentage of Planned Duration	MAT	IC	TD	TL	SAF	W	WC	RSC	Total
Prior to SA00	0	0	0	0	0	0	0	0	0
0%-10%	0	0	0	0	0	0	0	0	0
10%-20%	0	0	0	0	0	0	0	0	0
20%-30%	0	0	0	0	0	0	0	0	0
30%-40%	9	12	9	0	0	1	0	0	31
40%-50%	5	13	7	0	0	2	0	0	27
50%-60%	11	8	3	0	0	1	1	0	24
60%-70%	3	9	3	0	0	0	0	0	15
70%-80%	0	5	1	0	0	0	1	1	8
80%-90%	4	3	2	0	0	2	0	1	12
90%-100%	0	0	0	0	0	0	0	0	0
Post-Planned CA00	0	0	0	0	0	0	0	0	0

Table 60. NORFOLK (SSN 714) CM

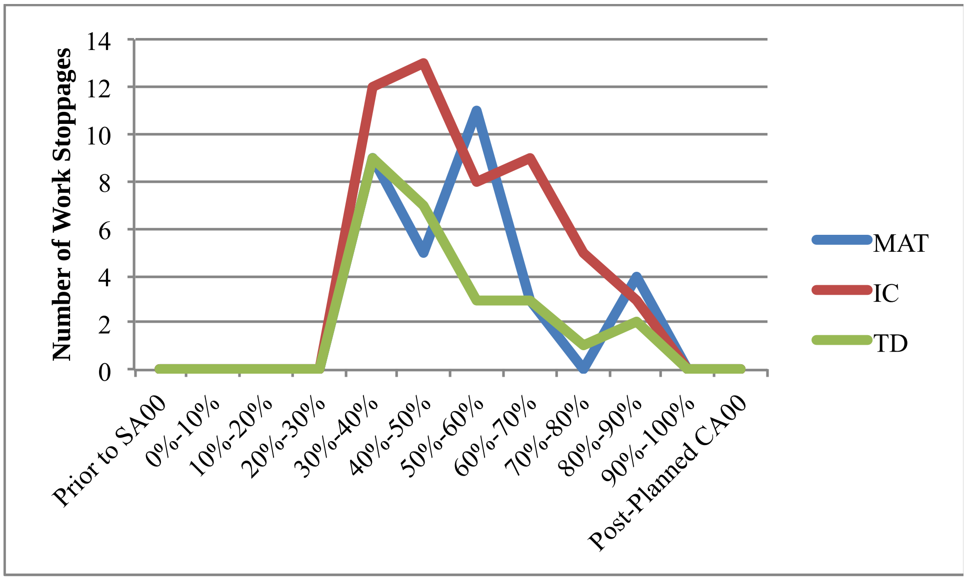

Figure 33. NORFOLK (SSN 714) CM

Point in Time of Availability	EISENHOWER PIA (58 Days Late)	WASHINGTON SRA (26 Days Late)	COLUMBUS DSRA (19 Days Late)	MICHIGAN MMP (14 Days Late)	STENNIS PIA (1 Days Late)	NORFOLK CM (5 Days Early)
10%	66.03%	60.66%	30.86%	93.80%	28.68%	0.00%
20%	50.14%	38.76%	22.33%	35.44%	12.49%	0.00%
30%	37.16%	20.22%	14.30%	28.47%	7.86%	0.00%
40%	28.15%	16.41%	12.95%	13.99%	5.22%	0.00%
50%	23.63%	12.98%	11.31%	9.78%	3.57%	0.00%
60%	20.14%	11.34%	11.00%	7.59%	2.73%	0.00%
70%	16.41%	11.30%	9.92%	6.54%	2.36%	0.00%
80%	15.10%	10.65%	9.75%	5.88%	2.26%	0.00%
90%	13.85%	10.49%	9.48%	5.82%	2.23%	0.00%
100%	13.56%	10.18%	9.04%	5.56%	2.22%	0.00%
Post-Planned CA00	12.91%	9.52%	8.79%	5.42%	2.22%	0.00%

Table 61. Pre-availability Work Stoppage Ratio

B. RED COLOR-CODED WORK STOPPAGE DATA SETS

Percentage of Planned Duration	Work Stoppage Reason								
	MAT	IC	TD	TL	SAF	W	WC	RSC	Total WS
Prior to SA00	24	8	36	0	0	0	0	0	68
0%-10%	5	4	2	0	0	1	0	1	13
10%-20%	7	3	9	0	0	0	0	0	19
20%-30%	10	8	4	0	0	0	1	2	25
30%-40%	7	23	13	0	9	0	1	6	59
40%-50%	6	20	4	0	0	0	1	6	37
50%-60%	9	20	30	2	0	1	1	9	72
60%-70%	22	55	15	0	0	0	2	2	96
70%-80%	24	29	18	0	0	0	2	5	78
80%-90%	31	25	16	0	0	2	9	3	86
90%-100%	2	6	1	0	0	1	3	0	13
Post-Planned CA00	30	16	10	0	0	4	15	0	75

Table 62. EISENHOWER (CVN 69) PIA

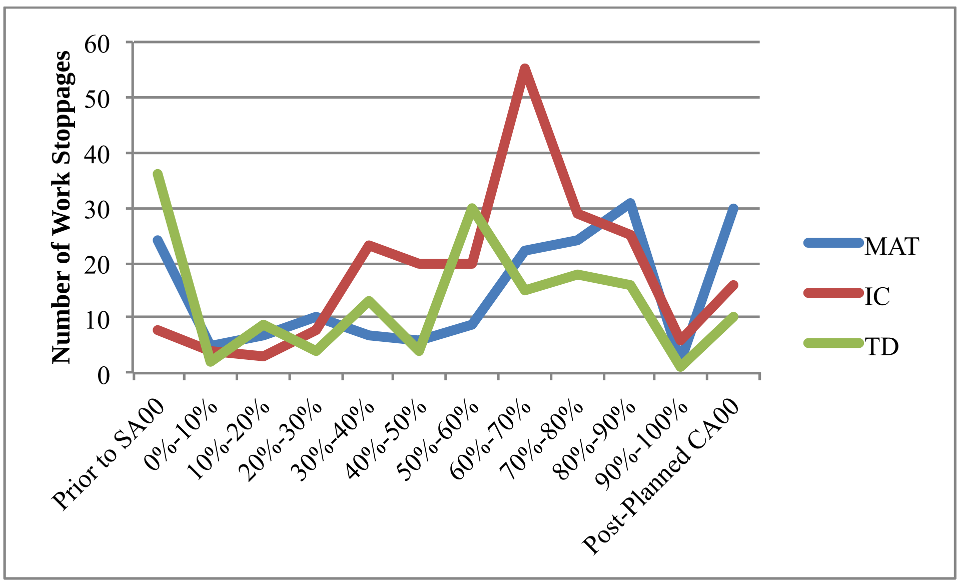

Figure 34. EISENHOWER (CVN 69) PIA

Percentage of Planned Duration	Work Stoppage Reason								
	MAT	IC	TD	TL	SAF	W	WC	RSC	Total WS
Prior to SA00	5	3	4	0	0	0	0	1	13
0%-10%	1	0	1	0	0	0	0	0	2
10%-20%	0	1	4	0	0	0	0	0	5
20%-30%	5	5	4	0	1	3	1	1	20
30%-40%	3	0	2	0	0	0	0	1	6
40%-50%	5	1	4	0	0	0	2	0	12
50%-60%	7	0	9	0	0	0	1	0	17
60%-70%	0	0	0	0	0	0	0	0	0
70%-80%	1	0	0	0	0	0	0	0	1
80%-90%	0	0	0	0	0	0	0	0	0
90%-100%	0	0	0	0	0	0	0	0	0
Post-Planned CA00	6	0	3	0	0	0	3	0	12

Table 63. GEORGE WASHINGTON (CVN 73) SRA

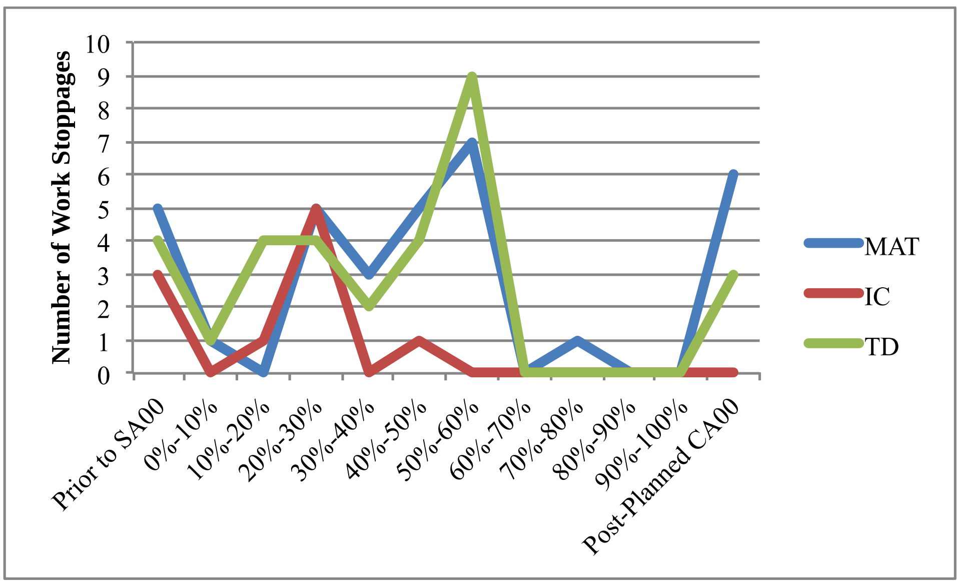

Figure 35. GEORGE WASHINGTON (CVN 73) SRA

	Work Stoppage Reason								
Percentage of Planned Duration	MAT	IC	TD	TL	SAF	W	WC	RSC	Total WS
Prior to SA00	4	2	4	0	0	0	3	0	13
0%-10%	6	6	5	1	0	0	2	2	22
10%-20%	4	4	4	0	0	0	0	0	12
20%-30%	8	15	18	0	0	1	3	1	46
30%-40%	0	4	5	1	0	0	0	1	11
40%-50%	4	13	6	3	0	0	4	2	32
50%-60%	2	4	1	0	0	0	0	0	7
60%-70%	1	11	12	0	0	0	3	5	32
70%-80%	0	4	0	0	0	0	0	0	4
80%-90%	1	2	2	0	0	0	1	0	6
90%-100%	0	18	7	0	0	0	1	1	27
Post-Planned CA00	2	5	8	0	0	0	0	1	16

Table 64. COLUMBUS (SSN 762) DSRA

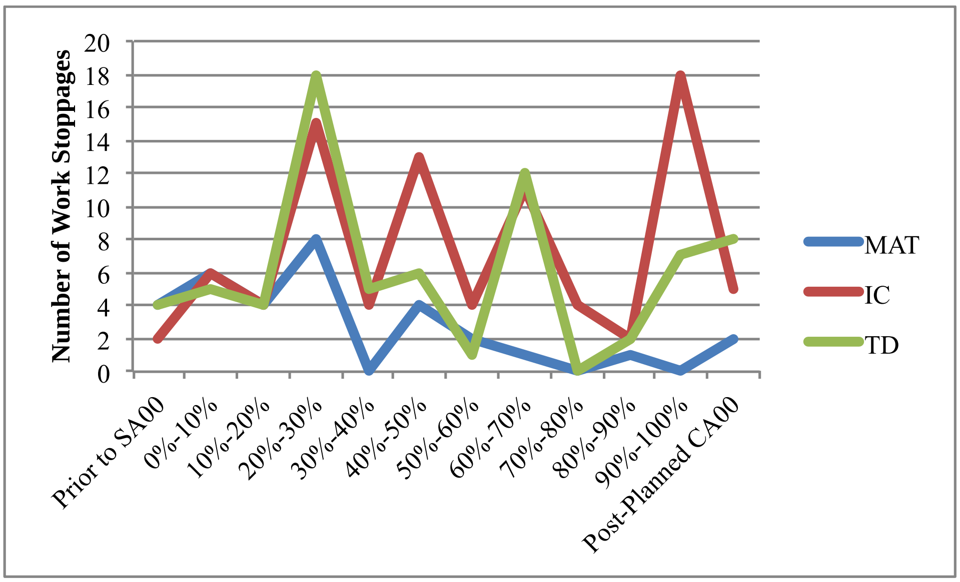

Figure 36. COLUMBUS (SSN 762) DSRA

Percentage of Planned Duration	MAT	IC	TD	TL	SAF	W	WC	RSC	Total WS
Prior to SA00	6	1	1	0	0	0	0	0	8
0%-10%	0	0	0	0	0	0	0	0	0
10%-20%	5	4	2	0	0	0	1	1	13
20%-30%	1	3	1	0	0	0	0	0	5
30%-40%	4	20	1	0	0	0	0	1	26
40%-50%	18	10	3	1	0	0	1	0	33
50%-60%	14	30	3	0	1	0	0	2	50
60%-70%	6	11	1	0	1	0	1	0	20
70%-80%	10	4	1	0	0	0	0	0	15
80%-90%	0	1	0	0	0	0	0	0	1
90%-100%	1	13	0	0	0	0	0	0	14
Post-Planned CA00	1	6	0	0	0	0	0	0	7

(Column group heading: Work Stoppage Reason)

Table 65. MICHIGAN (SSGN 727) MMP

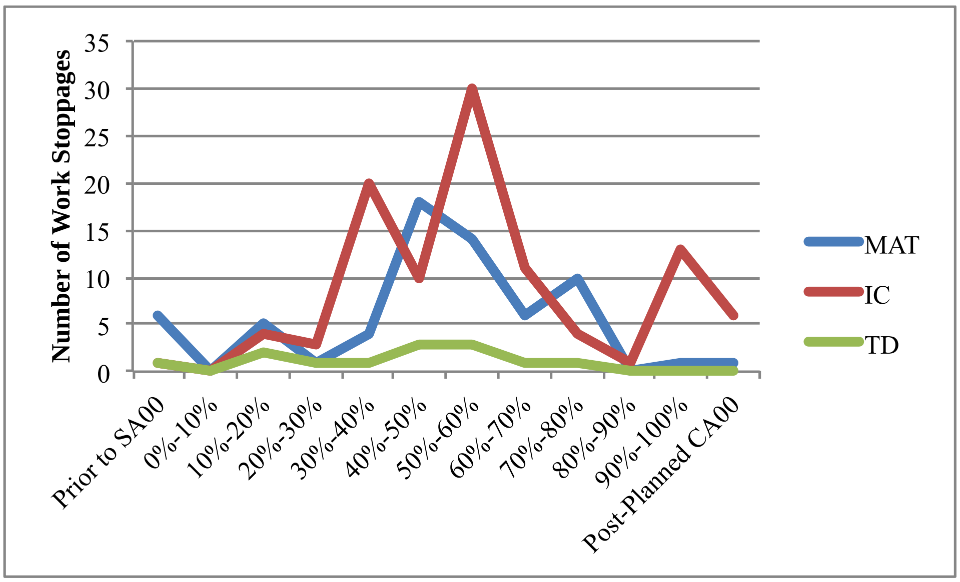

Figure 37. MICHIGAN (SSGN 727) MMP

	Work Stoppage Reason								
Percentage of Planned Duration	MAT	IC	TD	TL	SAF	W	WC	RSC	Total WS
Prior to SA00	0	0	0	0	0	0	0	0	0
0%-10%	1	3	1	0	0	0	1	0	6
10%-20%	2	3	0	0	0	0	0	0	5
20%-30%	1	5	6	0	0	0	1	0	13
30%-40%	3	7	2	1	0	0	0	0	13
40%-50%	6	33	5	0	0	3	2	0	49
50%-60%	7	25	12	0	0	1	3	3	51
60%-70%	16	25	9	1	0	0	2	4	57
70%-80%	7	3	1	0	0	0	2	0	13
80%-90%	2	6	0	0	0	0	1	0	9
90%-100%	4	1	2	0	0	0	2	0	9
Post-Planned CA00	1	0	0	0	0	0	0	0	1

Table 66. JOHN C STENNIS (CVN 74) PIA

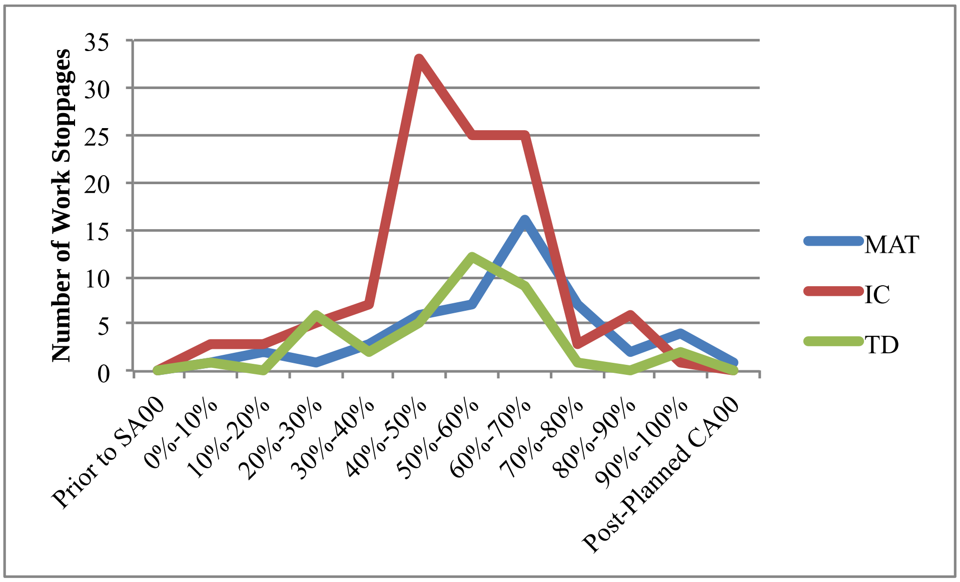

Figure 38. JOHN C STENNIS (CVN 74) PIA

Percentage of Planned Duration	MAT	IC	TD	TL	SAF	W	WC	RSC	Total WS
	Work Stoppage Reason								
Prior to SA00	0	0	0	0	0	0	0	0	0
0%-10%	0	0	0	0	0	0	0	0	0
10%-20%	0	0	0	0	0	0	0	0	0
20%-30%	0	0	0	0	0	0	0	0	0
30%-40%	3	5	5	0	0	0	0	0	13
40%-50%	0	6	3	0	0	0	0	0	9
50%-60%	6	6	1	0	0	1	1	0	15
60%-70%	1	8	3	0	0	0	0	0	12
70%-80%	0	3	0	0	0	0	1	1	5
80%-90%	3	2	2	0	0	2	0	1	10
90%-100%	0	0	0	0	0	0	0	0	0
Post-Planned CA00	0	0	0	0	0	0	0	0	0

Table 67. NORFOLK (SSN 714) CM

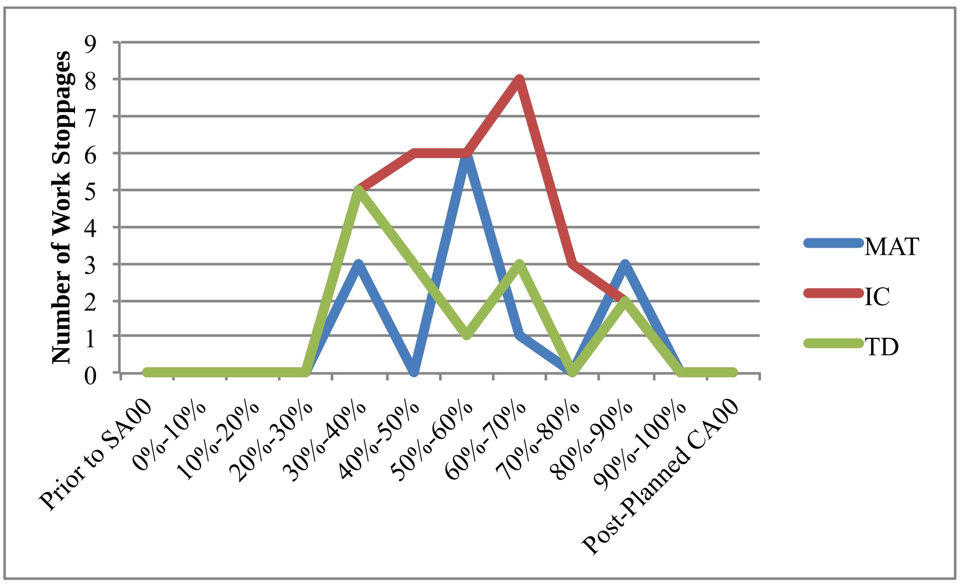

Figure 39. NORFOLK (SSN 714) CM

Point in Time of Availability	EISENHOWER PIA (58 Days Late)	WASHINGTON SRA (26 Days Late)	COLUMBUS DSRA (19 Days Late)	MICHIGAN MMP (14 Days Late)	STENNIS PIA (1 Days Late)	NORFOLK CM (5 Days Early)
10%	83.95%	86.67%	37.14%	100.00%	0.00%	0.00%
20%	68.00%	65.00%	27.66%	38.10%	0.00%	0.00%
30%	54.40%	32.50%	13.98%	30.77%	0.00%	0.00%
40%	36.96%	28.26%	12.50%	15.38%	0.00%	0.00%
50%	30.77%	22.41%	9.56%	9.41%	0.00%	0.00%
60%	23.21%	17.33%	9.09%	5.93%	0.00%	0.00%
70%	17.48%	17.33%	7.43%	5.16%	0.00%	0.00%
80%	14.56%	17.11%	7.26%	4.71%	0.00%	0.00%
90%	12.30%	17.11%	7.03%	4.68%	0.00%	0.00%
100%	12.01%	17.11%	6.13%	4.32%	0.00%	0.00%
Post-Planned CA00	10.61%	14.77%	5.70%	4.17%	0.00%	0.00%

Table 68. Pre-availability Work Stoppage Ratio

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